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COMPUTER MEDICINE

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Editorials

The editors feel compelled to comment on Volume XLV, No. 2. This issue is vastly different in concept from the others this year, and in fact, from most previous editions of the University of Toronto Medical Journal. It deals with a subject which the vast majority of medical personnel know little about, and which has moreover, little practical application in medicine at the present time. Nevertheless, few disagree that the widespread use of computers in medicine is just around the corner, and that an era swiftly approaches when every aspect of our discipline will be profoundly influenced by these exciting machines. The present undergraduate curriculum, overtaxed as it is by new developments in every field, has as yet no provision for instruction in data processing and computer technology. As a result many medical students and doctors regard these subjects as the exclusive domain of the electrical engineer and mathematician. They fear not only that understanding the basic principles involved is impossible without arduous training, but also that computers will somehow remove from the hands of the physician, decisions affecting the ultimate welfare of the patient. It was therefore considered necessary by the editors, when preparing for Volume XLV, that an issue be devoted to an explanation of computers — the principles of their function and the general areas where they will someday play a vital role. This issue clearly points out that computing machines are not mysterious black boxes with a myriad of complex dials and buttons, but probably the most valuable adjunct to medical education, research, and clinical practice that has yet been developed. We feel that, provided the student or graduate brings to this issue slightly more concentration and diligence than is usually required, he can understand most of what is written. Some terminology may be difficult and in truth, a few specific concepts impossible to understand, but these have been held to an absolute minimum. The general principles have been clearly outlined, and for the well-informed physician of today their understanding is an essential responsibility.

We are most fortunate to have Messrs. William Cass and William V. Weiss as associate editors of this issue, as they are uniquely qualified in the undergraduate body to undertake such a task.

Bill Cass is in his final year of medicine at the University of Toronto. He is a graduate industrial engineer (Toronto 1964) and has spent his last four summers working with computers. In 1965 and 1966 he was an associate systems engineer for IBM (Canada) Ltd. The editors are indebted to him for his long hours of work on this issue.

Bill Weiss is also in his final year of medicine at the University of Toronto. He graduated from electrical engineering (M.I.T. 1962) and then spent 2 years in industry prior to returning to medical school. During this time he gained extensive experience in the use of computers. For the past four summers, he too has applied his knowledge of data processing to medical problems (in 1966 he worked at the Manned Spacecraft Centre in Houston, Texas dealing with astronaut biomedical data management).

The article on computers in medical education was written by Paul Levy, presently a second year medical student at the University of Toronto. Paul has been interested in computers for a long time and also in medical education, as he has represented his year on the staff-student council. His paper, in our opinion one of the most exciting to ever appear in this medical journal, holds out promise that in the near future, medical education will be vastly different, and improved.

We have violated tradition in this issue by having, in Mr. McElroy and Dr. Shepley, non-undergraduates as contributors. Their articles are of great interest and because of the subject material in this issue, we feel the violation is excusable.

We should like to close with one thought. Medicine will always remain an inexact science and at least in part, an art—but the more exact we can make it, the better will be our final common goal—the healing of sick human beings.

W.K.L. D.A.L.

Four years ago candidates seeking admission to the first medical year were requested to attend an interview. One candidate, with an engineering background, was asked why he wanted to come into medicine. He replied quite candidly that he hoped to apply his engineering training to medical problems. In many ways the fields of engineering and medicine overlapped each other and in some ways one could be considered as an extension of the other. The interviewers were quite amused and snickered, albeit

politely. Since that time profound inroads have been made by technology in the medical area so that to-day computers and electronics are very much a part of the activity of modern medicine. To-day there are no formal boundaries between disciplines. Indeed the whole field of medicine can be considered as a sphere surrounded by and in contact with other spheres representing other fields of knowledge. At first medical people had been slow to accept this but to-day the team approach to medical problems is rapidly becoming a medical password.

The history of computers in medicine dates back to 1959. At that time IBM sponsored its first annual symposium on computers in medicine and representatives from across the continent gathered in Poughkeepsie, New York to discuss common problems and share ideas. Much of the effort that has been expended since then has been in individual pockets of research and development. As computer potential was transformed into medical reality more and more centres became interested in the new field. To-day, there are at least a dozen medical schools in the United States that have their own computing systems, and almost without exception, computers are a part of the future plans of all medical schools. Most noticeably, plans for a computing institute have been incorporated into the new Medical Sciences complex at this university and the McMaster Medical School is planning to have computing capability as part of its facilities.

With so much activity we feel it is necessary to add a word of caution. Primarily because of the financial considerations and the type of serious errors which can occur from the unintelligent use of computers, it is necessary to stress the serious and detailed planning which must be done before acquiring computers. It is a foolish and dangerous policy to get a computer merely because other medical centres are getting them.

From the very beginning one problem has persisted—the communication gap between the two disciplines. The potential for computer applications in medicine is unlimited but the problems of medicine must be interpreted into a language which is readily processable by the computer. In the past the work was done by teams of doctors and engineers. In order to fully realize the potential available we are going to need people schooled in the fundamentals of both sides. We feel that this can most adequately be done by incorporating computer principles into the medical curriculum. In this way doctors will not regard the computer as a "foreign" instrument and by the time medical students graduate and become actively involved in clinical practice or research, they will be able to structure their thinking in such a way that computers can be used in the problem-solving process.

What is the future of computers in medicine? Those who claim we are trying to produce push button doctors are foolish and misinformed. We are, however, about to enter a medical revolution and many of the old ideas are going to have to give way to newly discovered facts. In a word, we have been given a black box of potential and it will be our responsibility to develop this potential into meaningful medical applications. We must think and be creative. We must be flexible enough to accept new ideas and use them. To borrow a phrase, "That which we in medicine now hold to be a 'sacred cow' is in reality a large part bull."

The time has come to stop talking philosophically about the possibilities of marrying the two disciplines. In this journal we have tried to present the concept of a computer and using this as a basis, have presented four areas where applications already exist and are being used. We have not even scratched the surface. A survey of almost any modern medical publication outlines some other area where computers are being used. We have been privileged in putting together this issue of the Journal for to us fell the responsibility of chronicling the future rather than the past. It was a unique experience for us, and for the Journal. This is the first time an issue has been devoted to computers in medicine — undoubtedly more will follow in the years to come.

W.C. W.V.W.

Guest Editorials

MR. RON YAMADA

Ron Yamada graduated from the University of Western Ontario in Electrical Engineering in 1964. Upon graduation he joined IBM and gained extensive experience in a variety of manufacturing industries, culminating in his appointment as systems engineer at the University of Western Ontario. Part of his responsibility involved electrocardiographic research and analysis in conjunction with the Department of Physiology in the Faculty of Medicine. In 1966 he joined the IBM Medical Team in Toronto and recently has been promoted to the position of Regional Medical Coordinator for IBM.

In joint endeavours with outstanding medical centres such as Johns Hopkins, the Mayo Clinic, Downstate Medical Centre, the Ford Hospital, and the San Francisco Medical Centre, the IBM Corporation has in the past decade gained tremendous insight and experience into the philosophies, objectives, and problems of the medical community. In these centres, the areas of application include Clinical Decision Support System, a diagnostic aid to the physician, physiological monitoring, multiphasic screening, ECG Analysis, and information retrieval of medical records.

In this time, several outstanding problems have been established. One of these, the communication problem within the medical-engineering-data processing "love triangle" has been discussed in a previous editorial. As a result, I shall address my comments to the problem of the proper usage of a computer in medicine. This was vividly illustrated during a recent visit to the Los Angeles County Hospital's Circulatory Shock Unit. Here, using a system under the direction of Dr. Max Weil, a computer continuously monitors 12 to 16 physiological parameters, analyzes them, and displays this information on a typewriter within the Shock Unit itself. This is further shown on a closed circuit television screen for ease of reading. However, residents on duty have become acclimatized to saying "What does the computer say" or "What is the latest computer report" never looking at the patient's colour, or noting his respiratory rate.

This attitude can and does create severe problems. A physician's personal judgment based upon his education, training, and experience is all important and the computer only serves to reinforce and extend his diagnostic capabilities.

Let me put it another way. To quote a famous saying "In the beginning . . ." a physician had only his five senses to observe the patient's symptoms. Since then, X-rays, electron microscopes, and other instruments have extended the basic senses and assisted in the observation of phenomena critical to accurate diagnosis. The computer should be viewed in the same way.

As with any new piece of equipment, there is a period of adjustment where one must familiarize him or herself with this device. There is, however, a significant difference between this and previous devices. That is, for the first time, medical personnel can impart some of their logic and thought processes to a computer, and can "program" within the computer some of the decision making routines that are commonly employed. With this new capability, historical data can be processed, analyzed and used for the basis of predictive studies in such areas as physiological monitoring and ECG Analysis. In order to realize this potential, several things are required.

First, members of the medical community have a responsibility to assume an aggressive leadership role if the proper use of computers in medicine is to become a reality. It is the responsibility of the physician to determine and define the areas of medicine where this powerful and sophisticated tool can be most beneficially employed.

Secondly, medical educators must clearly communicate to the medical student computer concepts, limitations and capabilities.

Thirdly, the computer manufacturer must realize and accept the time and effort required to train its personnel in order that they may become conversant with the medical community.

Given these basic ingredients, I am confident that we as a team, can effectively work towards a common purpose, the combating of disease and improvement of patient care by the optimum use of all the modern tools at our disposal.

Dr. Morris Collen, Director of the Kaiser Permanente Foundation, at a recent United States Senate Hearing, concluded his report with a statement appropriate to this editorial. He stated, "it is our belief that the advent of computers and automation to medical care inaugurates a new, exciting, and rewarding area of medicine."

MAX HARRY WEIL, M.D.

Dr. Weil received his MD degree from the medical school, State University of New York in 1952. In the years 1952-57, Dr. Weil interned, took residency training and pursued his Ph.D. in cardiovascular physiology at the University of Minnesota. He was a Fellow in cardiology and cardiopulmonary physiology and a special Research Fellow (United States Public Health Service) at the Mayo Foundation 1956-57.

From 1957 to 1962, Dr. Weil completed and received his certification in Internal Medicine, holding posts as Chief Cardiologist (City of Hope Med. Centre, Duarte, Calif. 1957-59) and Attending Physician in Internal Medicine, and Senior Attending Physician in Cardiology, Los Angeles County Hospital, Children's Division.

Dr. Weil was appointed Associate Professor of Medicine, University of Southern California Medical School in 1963.

In the past five years, Dr. Weil has been extremely active in the application of computers to the study of shock. Dr. Weil & collaborators have published extensive literature in this area. Dr. Weil, as Director of the Shock Research Unit, U.S.C. Med. School is presently continuing to lead the field in computerized physiological monitoring.

The availability of competent hospital services is now justly regarded by the patient as his right rather than his privilege. An extensive critique published February 4, 1967 in the Saturday Review, "What's Wrong with American Hospitals", details both the frustration of the patient and hospital administration. The hospital administrator may strive to supply competent services. However, he is continually confronted by the very practical problem of implementing the benefits of scientific medicine, yet he is limited by availability of qualified staff, instrumentation, and physical facilities. Clearly, the number of patients who are to be served and the complexity of services which now constitute acceptable hospital care have overwhelmed available resources. A revolutionary change in the operation of hospital facilities is needed if the hospital is to keep up with the ever-increasing demands for hospital services.

For these reasons, hospital administrators and directors are increasingly looking to automated systems, particularly to computer facilities for a solution. Favorable experience with computers in accounting applications (including hospital accounting), process control applications as in oil refineries, and control operations as in the distribution of electric power, regulation of traffic signals and airline reservations, all offer practical examples of tasks which have significant parallels in the hospital environment.

Inherent in the development of automated facilities is the development of competent sensors, amplifiers, recorders, display modules, and storage facilities with which to gather and process information. The information from sensors may have to be converted by analog or digital processing devices before it can be stored by the computer. The stored information may then be further processed and analyzed to obtain information on the basis of which a course of action is determined. For example, the patient's name, sex, birthdate and current address are printed on a suitable form by the patient or a member of his family. This information is entered into the computer system by the admissions clerk with the use of an optical reader. This information is simultaneously logged in several places such as the business office, telephone switchboard, and laboratory. The store of information available to the computer is automatically searched to determine whether a patient by the same name, sex, and birthdate, has previously been admitted to the hospital. If so, the information is communicated to the admissions clerk, along with any prior address listed in the file. When the identity of the patient has been confirmed by the clerk, an appropriate new or old hospital number is assigned to the patient. This information is displayed to the clerk and simultaneously communicated to the business office, X-ray Department and other stations in the hospital where a daily patient log is maintained. Current admission practice, on the other hand, entails an array of manual routines with the creation of a large number of handwritten and typewritten records, and manual search of the hospital records. This operation requires a generous allocation of personnel, and infringes on already congested communication links.

At the present time, the computer is already well established as a major aid for those phases of hospital operation which involve business and the clinical laboratory management. In other aspects of hospital operation, we must regard the present state of computer automation as experimental. Interphases between man and machine are exceedingly difficult, particularly in a medical setting. There is need for improved and concise terminology to formulate patient history, physical examination, progress notes, surgical and pathological records, electrocardiographic and X-ray information. Furthermore, there is a need to convert this information into a form from which it can be assimilated by computers. The problems are less complex in the case of computer centered operation of the chemical laboratory. This operation has been successful because parallel advances in process control techniques in industry are well established. The elements of laboratory operation involve mechanical tasks which are now well defined and the output of the information is numerical.

Particularly attractive to physicians directly involved in the care of patients, especially in the care of critically ill patients, are the potential advances in concept, design and technical implementation of techniques which will improve the efficiency of bedside diagnosis and treatment. A problem inherent in the application of computers to bedside medicine is the availability of competent sensing devices. There is a need for reliable "hardware" to bridge the interphase between the patient and the sensor. Calibration and check routines are needed to assure validity and accuracy. The raw data is then converted into a form which is meaningful to the physician. The computer may function as an indefatiguable sentinel and issue pertinent alarms. To some extent, the operation of pumps, ventilators, cooling devices, and pacemakers would best be controlled by the computer, based on the orders of the physician. Current investments of critically limited nursing time for purely mechanical chores such as an adjustment of intravenous drips, ventilators, and many other devices in response to specific physician's orders would be minimized. A "closed loop system" which has been instructed to follow physician's orders is likely to do a much better job. A pertinent example would be the infusion of fluids at a fixed rate of 400 ml. per hour until venous pressure exceeds 10 mm. Hg. when infusion is slowed and the ward staff is alerted to the change.

In using computer techniques for purposes of diagnosis, the physician is not relegated to the role of an observer but rather becomes the central participant. The processor provides highly efficient mechanical sorting of information. The computer itself has neither insight nor judgment. It can only classify information, compute derived values and realign facts in such a way that relationships become obvious. Hence, the physician has a helpful tool with which his professional resources are bolstered, rather than a colleague. Information gathering may be simplified and statistical operations may be analyzed to identify missing data and objectify the reliability with which a diagnosis may be reached.

Though the realistic appraisal of current status emphasizes the hospital aspects of the present work, there are exciting possibilities for screening and detection of subclinical disease states in out-patient populations. Such work is already under way under the auspices of the Kaiser Foundation in San Francisco, California.

Finally, a brief comment is necessary on the importance of a new order of objectivity and generosity in professional relationships which are essential if great strides are to be made. Medical practitioners who would share in the benefits which are to accrue from automation and the use of computer techniques will have to form close alliances with colleagues in the physical sciences and particularly with engineering and biomathematical specialists. Some progress has already been made. There are joint biomedical and engineering programs in schools of medicine and engineering. Yet engineers and biomathematicians will have to be accorded even greater welcome and, in fact, the privileges, of full membership on the medical team.

Problems in instrumentation, systems design and operations are likely to be solved only if the dialogue between professional medical men and professional biotechnical personnel is achieved at that level. Many precedents for such alliances are at hand. The physicist has become an essential member of the radiological team and the clinical chemist an essential colleague of the clinical pathologist. The medical microbiologist has long held an honourable professional place in medicine. In the same way, the engineer, biomathematician, and related talents will hopefully become close professional associates of the hospital physician.

The Gist Of Electronic Computers

W. Cass, B.A.Sc. 6T8

It is a presumptuous thought to try to condense the concept of electronic digital computers into one article in a medically oriented magazine. The field is vast and no amount of words can replace one's own personal experience. To compound the problem there is no end to the number of myths associated with computers, and unfortunately this has led to many a prejudiced view and dampened the enthusiasm with which many learn about new concepts. The computer is not a *thinking* machine but rather a *calculating* machine. This article will attempt to present the concept of a calculating machine, and explain what effort is involved in order to break down problems into a machine-processable form. With this background, it is hoped that the medically-oriented reader of this journal will gain an insight into the medical applications which have been described.

Computers are data processing machines. There is a very definite distinction between "data" and "information". An item of data is a record of an event and hence it represents "facts". Everything that happens gives rise to new data. The passage of time itself can be considered as data items and often these are used as a basis for records of the events. In this sense, data is only the "raw material" of information. The generation of data or recording of events is an infinite process. Of the potential data that is available at any one time, we use only a small fraction. In order to be useful the raw material must be refined or processed into an end product which can be designated as "information". Hence the true purpose of data processing is to produce information.

Processing is a comprehensive term for the various operations which can be performed on the data. Data can be requested, manipulated, summarized, evaluated, analyzed and reported. The sequence in which these operations are performed will vary with the particular application at hand. The first step in any application, however, is constant and represents *data collection* or recording. This can be done in a variety of ways ranging from written reports, charts, and graphs, to holes punched in paper or cards and photographic images on film. In some situations it is possible that one will be dealing with very large quantities of data and so it becomes important that individual pieces of data be transformed into a form that can be easily manipulated. In other words the *data must be made mobile* and assume a degree of uniformity. As the volume of data continues to increase, so does the need for greater speed and flexibility. These requirements are met by machines which can take over a large part of the processing function. At the lowest level of machine-aided processing are adding machines and calculators. It soon becomes apparent that certain pieces of data can be used many times, in different ways, to produce different kinds of information. In many stages of the process it is necessary to physically *rearrange the data or combine* it with other items. In order to do this the *data must be retrievable*, i.e. in a form such that it can be readily used as often as required. In an adding machine, for example, one enters a number and the number is used only once and is not retrievable.

One of the most convenient methods for transforming information into a machine readable form is the punched card. These cards are commonly called unit records because units of data are punched into specific column locations on the card. This is accomplished with a keypunch and the data is represented as holes in each column. These holes allow electrical contacts to be made as the cards are fed through the machines which will be doing the processing and in this manner, the machine is said to "read" the card. The electrical impulses thus created cause the machine to rearrange the cards in various sequences, perform arithmetic upon the numbers that the impulses represent and actuate printing devices which transform the impulses into printed characters. Card-actuated machines can process more data and extract more information from data in a shorter period of time and at less cost than manual methods. Also, once the data is punched into cards, the cards can be used many times in a variety of ways to produce different types of information.

In a punched card system each operation generally is performed by a separate machine and collectively these machines are known as a unit record system. One machine may be used solely to sort the cards into a desired sequence; another, to merge groups together or to select certain cards or groups of cards from a previously sequenced file. Still other machines are used to add certain items of data together from separate cards or from the same card; to perform multiplication, division, and subtraction; to determine whether certain items are greater or less than others; or to print the punched information directly on the card itself or onto continuous paper forms.

Unit record equipment can be considered as half-way between manual processing of data and a fully automated data processing system or computing system. In a unit record system one machine reads the cards and performs a particular processing function extremely rapidly. If a second operation is required the punched cards must manually be fed into the same or another machine and again the cards are read and the necessary processing performed. In a computing system the data

is read at once, along with a list of instructions detailing what is to be done with the data, and processing proceeds uninterrupted to completion.

"Computer" is really a word describing a complex of equipment rather than one machine. It is better referred to as a computing system. There are five basic components in a computing system which can be summarized as follows: (1) input, (2) output, (3) memory, (4) arithmetic, (5) control.

The input unit is used to transfer data into the system. There are many ways in which this can be done. The punched card has been described previously, and it follows that one type of input device is a card reader. Data can also be entered into a system by typing it on a keyboard, punching it on a paper tape and feeding this through a paper tape reader, or reading from a magnetic tape (to be described in greater detail with the memory component). Usually there is more than one input device per system and the exact combinations are determined by the overall requirements the system must fulfil.

The output unit enables the computing system to communicate with the outside. Often this communication is the information which the system is being asked to calculate but may also be messages that require the person operating the system to take some action to enable the system to continue operating. Output can be typed by a system-controlled typewriter, printed onto a continuous form by a printer, or displayed on a television-like screen. Sometimes the output from one particular application is a set of data which is to be used at a later time. In this case the output can be "printed" onto magnetic tape or punched onto cards or paper tape by a system-controlled card or paper-tape punch respectively. In other words the ouput from one processing job can be the input to another.

The memory unit stores all data entered into the system, and all the information generated by a particular application, along with the instructions that enable the system to process the data. There is no intrinsic memory in computing systems; there is a finite limit to the amount of data which can be stored. The bigger the memory, the bigger and more flexible the system will be. The memory unit that represents one of the five basic components is called core. It is possible to augment core with auxiliary memory or storage capacity. This is accomplished with magnetic tape or discs. Unlike the punched card where data is represented by holes, on magnetic tape or disc data is stored as magnetized spots. Data is read from tape at much greater speeds than is possible with the card reader and as indicated previously, the tape can be used for input or output functions.

The arithmetic component of a computing system is the area in core reserved for performing arithmetic operations, i.e. addition, subtraction, multiplication, and division. Associated with this area are the instructions required to enable these operations to occur.

The control unit acts to coordinate all the activity required in the proper functioning of the computing system. There are no inherent actions in a computing system. It operates by performing one thing at a time but these operations are performed at extremely high speeds. The control unit is the necessary part of the system that ensures that the other components will be coordinated in executing this sequence of events.

The actual machinery that comprises the computing system is referred to as "hardware". At the heart of the system is the control processing unit (CPU). In general, all computer control processors include the memory unit, the arithmetic unit, and the control unit. The actual design of a specific computer configuration will be determined by a host of factors, the most important being cost and usefulness.

Computers have often been described as high speed morons. They know nothing except what they are told and can do nothing except in response to a set of instructions given to them. There are two types of instructions which a computing system requires. The first is a set of instructions built into the control unit for the operation of the system. For example, when a card is ready instructions are required to transmit the data to core, store it there, and set up an internal system whereby the data will be easily recoverable. Furthermore internal instructions are required to ensure that no two pieces of data are stored in the same location else the first will be lost. These instructions are part of the "software" associated with a computing system. Basically, software represents anything and everything related to an electronic computer that is not present in tangible hardware. Other parts of the software package include programming languages, prewritten utility programs, and systems supervisor routines. The programming languages are the method of communication between the potential user and the system. In order to use a computer to solve problems or process data, it is necessary to break the job down into individual logical steps which follow one another. This establishes the sequence which the computer will follow. It is necessary to specify this sequence to the computer and this is done by writing it out in a special language which is understandable both by the computer and the person using it. The transcription of a sequence of operations into a language which the machine understands is called *programming*, and in effect programmed instructions are created. These are the second type of instructions required by the computing system. Hence it can be seen that the computer is merely an instrument which does precisely as it is instructed to do—nothing more nor less. It cannot interrupt a sequence of instructions, independently change any step, or ex-

ercise independent judgement. It is the function of the programmer to exercise judgement and prepare his program accordingly.

In light of the foregoing discussion the question remains as to how one learns enough about computers to be able to use them intelligently in a medical situation. The problem is primarily one of attitude—of placing the use of the machine in its proper perspective. The physician must overcome the fear that the machine poses a threat to his ability to exercise full control over operations, and realize that a computer, properly used, can increase his ability to exercise control by making more information available to him when he needs it. It is not important to know much about the machinery so long as it is realized that:

(1) The computer is only a tool, one component in a man-machine-information system.

(2) Information coming out of the machine can only be a combination or permutation of the data which went into it. The machine cannot create information, nor can it extract information which is not inherent in the raw data going in. This is best summarized by the acronym "GIGO"—garbage in, garbage out.

(3) Information coming out of the machine is useful only when it is interpreted in terms of the combined limits of error of the input data and the program which processed it.

Each of the articles which follow is an example of a computer application in the medical field. In each case it was necessary to approach the problem from the point of view of expressing it in quantitative terms. In each case human ingenuity reduced the particular problem into a machine-processable form. What is the gist of electronic digital computers? Computers are adjuncts which we have at our disposal for the solution of problems. If computers are intelligently used by people they are profound tools which will facilitate handling problems previously not even considered. Without human effort computers are like any electrical appliance with its cord pulled out.

Computer Analysis Of Cardiac Signals

*J. F. McElroy**

INTRODUCTION

Heart disease is perhaps the most significant medical problem of modern medicine. Approximately 75,000 or 51% of all deaths occuring annually in Canada are caused by some form of cardiac disease. In the United States of America nearly one million persons died from heart disease in 1963.[1] There is no indication of any immediate decrease in these figures.

The electrocardiogram historically has been one of the most valuable tools in the correct assessment of the presence or absence of heart disease. However, the electrocardiogram, like all tools of medicine, is constantly being refined and developed. The latest of these refinements is the coupling of the electrocardiogram with the most significant modern engineering achievement, the electronic digital computer.

Much has been written about the marriage of the computer and the electrocardiogram but there still remains an aura of mysticism in general concerning the use of computers in medicine. It is this erroneous mysticism, often sparked by groundless conservatism, which has in the past, and unfortunately still too often, hampered significant scientific gains in this field. Fortunately these attitudes are not universally held by those in control of research funds and significant work has proceeded at several major centers in the field of computer analysis of physiological signals, the most significant of this work being accomplished in the field of computer analysis of cardiac signals.

The electronic computer as described in Mr. Cass' article is simply an extremely accurate and rapid information processor. It is capable of performing a prodigous number of manipulations on information in an extremely short period of time. The fastest computers can now multiply one million twelve digit numbers by another one million twelve digit numbers in about one second.

As will be seen in this article the electrocardiogram is simply an electronic signal generated by the heart, containing a great quantity of information which can be processed by computer.

DEFINITION OF THE ELECTROCARDIOGRAM AND VECTORCARDIOGRAM

There are two commonly used methods of measuring cardiac signals employed today. These methods are

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the twelve lead electrocardiogram and the three lead vectorcardiogram. The main difference between the two methods besides the obvious difference in the number of leads is that the electrocardiogram represents the voltage of each individual lead, whereas the vectorcardiogram combines the three signals into a vector. This vector is a three dimensional representation of the electrical force generated by the heart and by displaying this vector it is easy to obtain pictorially the changing magnitude and direction of the electrical signals generated by the dipole of the heart.

The twelve lead electrocardiogram is the older and classical way of recording the cardiac electromotive force and is illustrated in Figure A. The various signals were originally defined as the P. Q. R. S. T and U waves by Einthoven and these terms are still in general use. It should be remembered that the electromotive force which is responsible for the P wave and the QRS complex occurs *before* the atrial and ventricular muscles contract and not as a result of their contraction.

The electrocardiogram is an electronic signal containing valuable diagnostic information. In order to derive the information the signal is fractionated into the various sub-signals related to the physiological processes occuring during cardiac contraction:

1) The P wave represents the depolarization wave of the artial musculature as the wave travels from the sinoatrial node to the atrioventricular node.

2) The QRS complex represents the depolarization of the ventricular misculature.

3) The T wave represents ventricular repolarization.

4) The U wave is a small, upright deflection sometimes seen following the T wave. Its significance is unknown.

In addition to the amplitude of the waves, the times between the waves, i.e., the segments and intervals are also of importance.

The *P-R segment,* which is measured from the end of the P wave to the beginning of the QRS complex, represents the delay in the transmission of the electrical impulse at the atrioventricular node.

The *S-T segment* is that portion of the wave between the end of the QRS complex and the beginning of the T wave. It represents the depolarized state of the ventricles.

The *P-R interval* is measured from the beginning of the P wave to the beginning of the QRS complex. The P-R interval represents the time required to depolarize the atrial musculature plus the delay in the transmission of the impulse through the atrioventricular node before the beginning of ventricular depolarization.

The *S-T interval* is measuerd from the end of the QRS complex to the end of the T wave and represents the time from the completion of depolarization of the ventricular musculature to the completion of repolarization.

The *Q-T* interval is measured from the beginning of the QRS complex to the end of the T wave. It represents the entire time required for depolarization and repolarization of the venticular musculature.

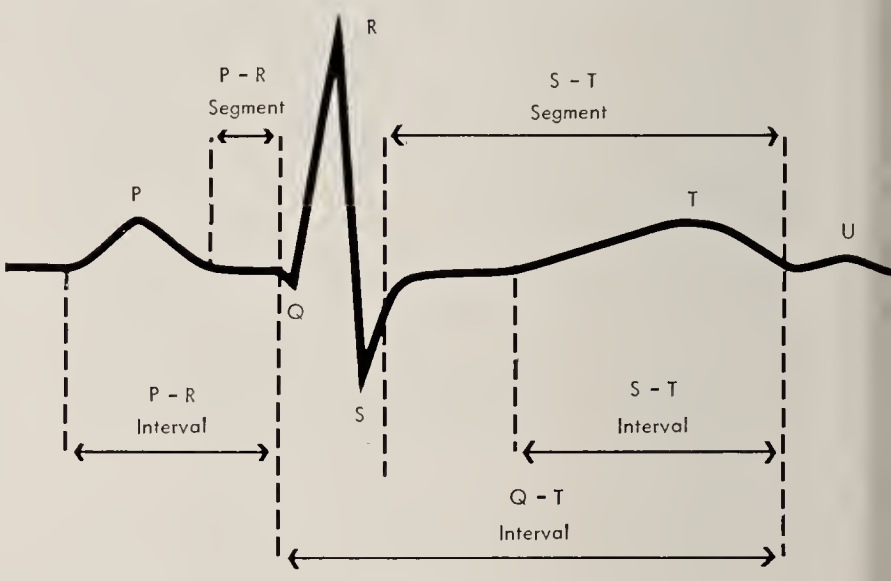

FIG. A.

These waves, segments and intervals are all very definitive in nature and over a period of years reasonable estimates of the ranges of normal values have been tabulated. All of these values are of course dependent on age, sex etc. They are, however, absolute bits of information which can be given to a computer to be used for comparison purposes.

COMPUTER ANALYSIS

Several systems have been developed at various medical centers, mainly in the United States, to analyse electrocardiograms and vectorcardiograms. Some of these centers are the Mayo Clinic, Harvard Medical School, Mt. Sinai Hospital in New York, George Washington University, and the U.S. Public Health Service in Washington D.C. The only Canadian project of note at the moment is being conducted at Dalhousie University. All of these systems are unique unto themselves, however, they do have certain common fundamental characteristics. Each system has some means of signal preprocessing, data recording, telemetry capability, analog to digital conversion ability, computer analysis and result reporting.

In a typical computer electrocardiographic analysis system as used at the Mt. Sinai Hospital in New York City, the ECG is recorded via the standard twelve leads, preprocessed to remove extraneous electrical noise and monitored via a strip chart recorder. Simultaneously the ECG signal is recorded on a frequency modulated (f.m.) tape recorder and/or transmitted directly to an

IBM 1401 computer. Here the ECG is digitized, and enters the computer memory. Systems similar in design to the Mt. Sinai Hospital system are installed at the George Washington University Hospital and the U.S. Public Health Labs.

At all of the above installations the signal preprocessing equipment, the monitoring equipment, the analog magnetic tape recorder and the telemetry equipment are contained on a portable cart which can be moved to a patient's bed. The electrocardiogram can then be transmitted from the bedside to the computer, utilizing ordinary telephone circuits.

By comparison, at the Mayo Clinic, due to the operational difference of the institution (in which a very large volume of electrocardiograms are recorded), several rooms are permanently wired for ECG recording. In fact, both the twelve lead electrocardiogram and the three lead vectorcardiogram are used. The resulting signals are then stored on a large fm tape recorder and run on the computer at a later time. During the last few years, over 100,000 vectorcardiograms have been analysed by the computer, an IBM 7044.[3]

At Dalhousie University utilizing an IBM 1800 computer and radio telemetering equipment, studies are presently underway to study continually the heart signals of fishermen as they work in their boats.[4]

In any system similar to the above, the power of the system is centered in the digital computer. Since the computer is digital in nature, the analog *or continuous* electrocardiogram must be converted into digital form. To do this an analog to digital conversion is carried out, each sample point of the ECG wave form being given a numerical value based on its amplitude. Each point is then labeled for future use and is stored in the computer memory. The number of sample points converted varies from system to system but is usually about 750 sample conversions per second. Once the data is stored, it is ready to be processed by the computer.

All computer electrocardiographic analysis programs are divided into two distinct sections, pattern recognition and "computerized" clinical evaluation. The pattern recognition logic is the more complex of these processes and has as its objectives the determination of the magnitudes and times of all wave forms, segments and intervals.

At first observation the pattern recognition seems like an almost impossible task, but like most complex decision processes it can be broken down into many logical steps. An example of part of a much simplified pattern recognition program is illustrated in Figure B. A more comprehensive description can be found by Steinberg et al.[6]

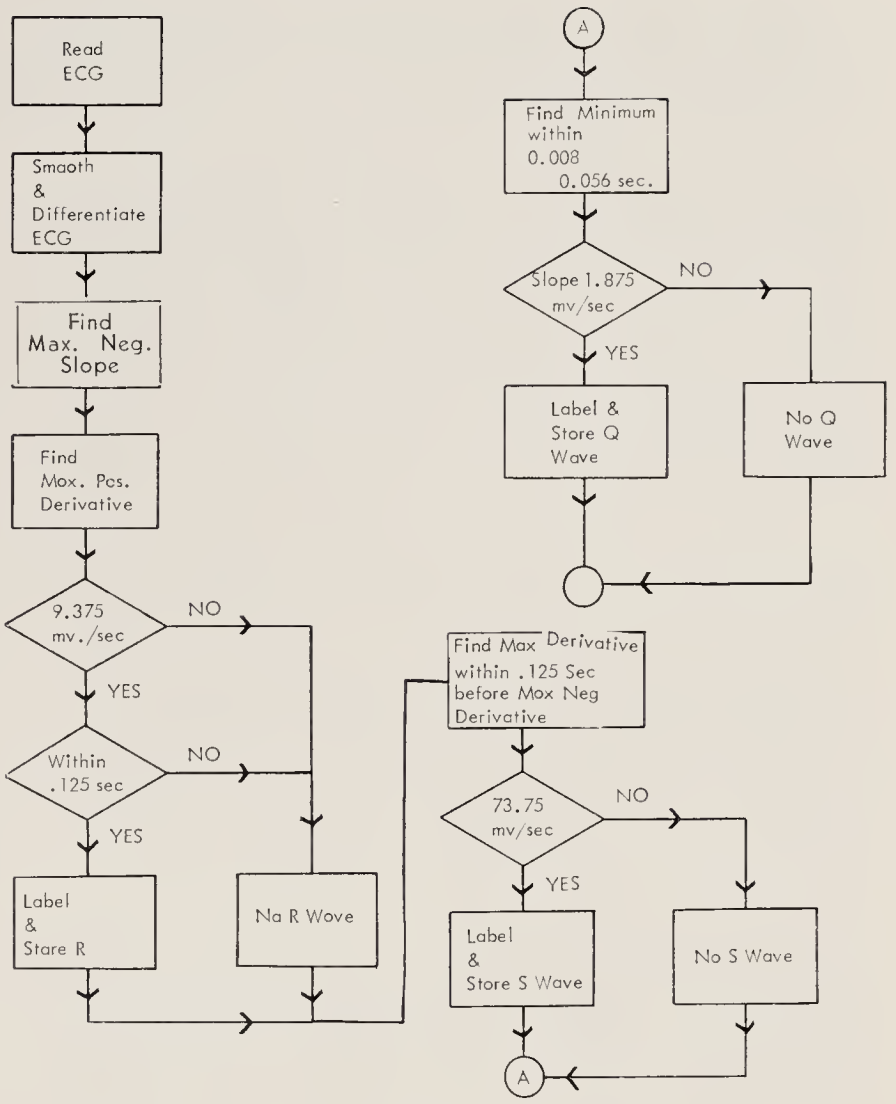

FIG. B.

Remembering that in a computer program only very small logic steps are taken, the first requirement is that a reference point from lead to lead and from subject to subject be established. This point is necessary for the computer to discern individual heart cycles. The best choice for this reference point is the point of greatest negative rate of change of the electrocardiogram. This point occurs during the QRS complex because the rate of change of potential is greatest at the time of ventricular depolarization. Once this point of reference has been determined complete heart cycles can be isolated and by simply inverting the time between succeeding beats the heart rate can be determined.

After a constant reference point has been established, it is next necessary to determine the existence or nonexistence of each of the waves. The presence of an R wave is determined by checking the value of the maximum positive derivative. If it is greater than 9.375 millivolts/sec. within .125 seconds before the maximum negative derivative, a R wave is present. If these criteria are not met then no R wave is present.

S waves are searched for by determining if the derivative is greater than 3.75 millivolts within .125 sec. before the maximum negative derivative. If S waves are present these criteria will be met, otherwise, S waves do not exist.

Q waves are found by searching for a minimum within 0.008 to 0.056 seconds before the R wave peak providing the slope is less than 1.875 millivolts/sec.

Once these waves and the remaining waves (the determination of which is extremely complex), have been identified and labeled it is necessary to determine their onset, peak and termination. These last determinations require very rigid mathematical calculations, and checks are used to ensure that the results are accurate. After the verification is complete all the segments, intervals and amplitudes are calculated and stored in the computer memory. This data is then ready for evaluation by the second section of the program.

The second section of the program allows the computer to produce a clinical evaluation. Computers have been programmed to perform this evaluation in several different ways. At Harvard the classical text book logical step procedure is followed. At Mt. Sinai, a system utilizing various QRS templates which are dynamically modified, is used[6] and at the Mayo Clinic a logical program has been developed for analysing vectorcardiograms.[7]

The system used by the Public Health Labs in Washington is perhaps the easiest to understand. A simplified version of one of the programs developed there is the following. The values determined for the waves, segments and intervals are stored in a large table in the computer memory. Next these determined values are matched against a corresponding table of normal ranges. When the determined values are matched against the normal table a third table is produced. This third table or matrix consists of one of three possible numbers for each entry or element, a minus one (-1) if the determined value is below normal, a zero (0) if the determined value is normal and plus one (+) if the determined value is greater than normal.

The computer also contains various "disease" tables filled with appropriate −1's, 0's and +1's. Each disease state, such as left ventricular hypertrophy, has its own unique table. The computer compares the data table and various disease tables until a match within certain confidence limits is made. When this match is made the computer can then print out a corresponding "computerized" analysis.

Obviously the comprehensive systems in operation, at least one of which can recognize forty different arrythmias, are much more complex than the above, simplified example. For example, they must take into account *combinations* of disease states. However, this example does point out the basic principle upon which computer analysis operates—the manipulation of data in a manner utilizing sequential logic.

SUMMARY AND DISCUSSION

It has been seen that the electronic digital computer is a machine capable of processing and analysing vast quantities of data. The electrocardiogram consists of just such data and when this data is properly analysed, it can be a valuable diagnostic tool. As has been mentioned, this combination has been successfully implemented at several locations with two of these, the Mayo Clinic and the United States Public Health labs, having already processed over 100,000 and 50,000 electrocardiograms respectively. As an example of the growing importance of this application the American College of Cardiology held a two day symposium on "Computer Applications in Clinical Electrocardiography" in 1967 in Washington, D.C.

It is felt that the computer will offer many advantages in analysing electrocardiograms both now and in the future. For example, the computer can store ECG's in auxiliary memory (tape or disc) for years and can use them for historical comparisons many years hence. Also the availability of such data, when correlated with automated clinical data also in a machine processible form, will allow large scale epidemiological studies to become feasible. This data will, of course, be used to further refine the diagnostic process. Finally, perhaps of most interest to the practising physician, the computer will provide a non-tiring, non-biased consistent evaluation of every electrocardiogram presented to it, whether that electrocardiogram be from the next room or from across the continent.

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Patient Physiological Monitoring

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Modern electronics is presently revolutionizing practices in the biological sciences. Although numerous applications of electronics in medicine (laboratory and research applications) never come face to face with practising clinicians, the thrust of electronics into the wards is becoming increasingly apparent in the expanding field of physiological patient monitoring.

One might question why these electronic tools have been neglected so long in medicine, when electronics has been flourishing since the close of World War II. The principal reasons were probably; prohibitive equipment costs, equipment was too bulky, operation was too complex, and many present-day transducers were not available. These problems were overcome with the spectacular miniaturization and instrumentation which resulted from research in the U.S. Manned Space Project. Another important development has been the "human engineering" now being incorporated into electronic devices, such that previously complex instrument adjustments are now built into the equipment, and thus, the previous multiplicity of knobs and dials has been largely eliminated.

An example of how this miniaturization has made complex electronics available might be instructive. A computer which ten years ago would have filled a room forty by forty feet, and at a cost of several million dollars, is now small enough to fit in a space not much larger than that a large refrigerator might occupy, and the cost is less than one hundred thousand dollars. It should also be added that today's model would have a much superior performance capacity.

Three approaches to physiological monitoring have appeared to date:

1. Monitoring of selected ward patients, or operating room patients with *isolated* instrumentation apparatus.
2. Monitoring of a whole ward *concurrently* with a patient monitoring "system".
3. The application of electronic digital computers to 1 and/or 2.

A survey of a large number of hospitals at the present time both in Europe and North America, would show that the first approach has been used most universally.

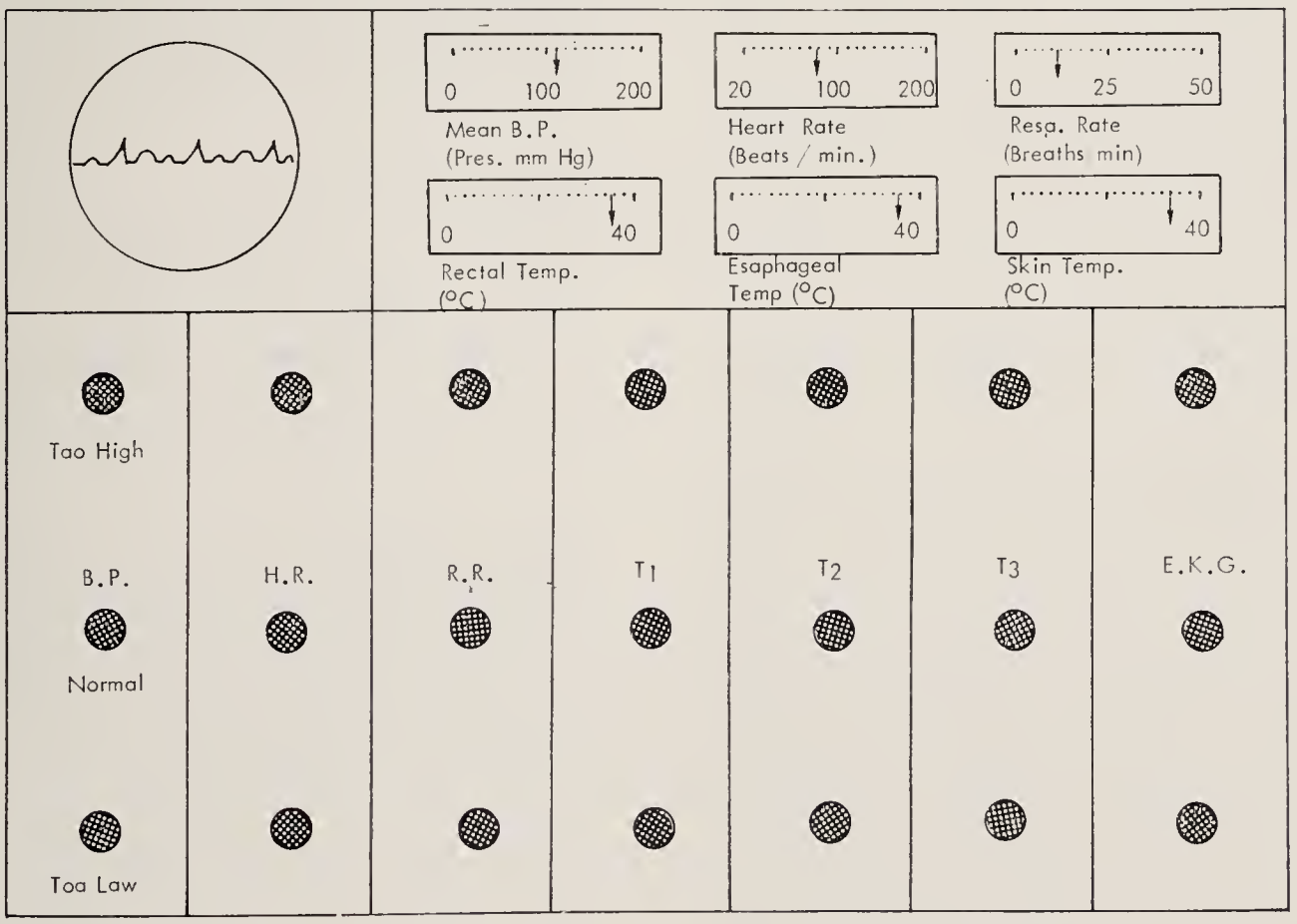

FIG. 1.

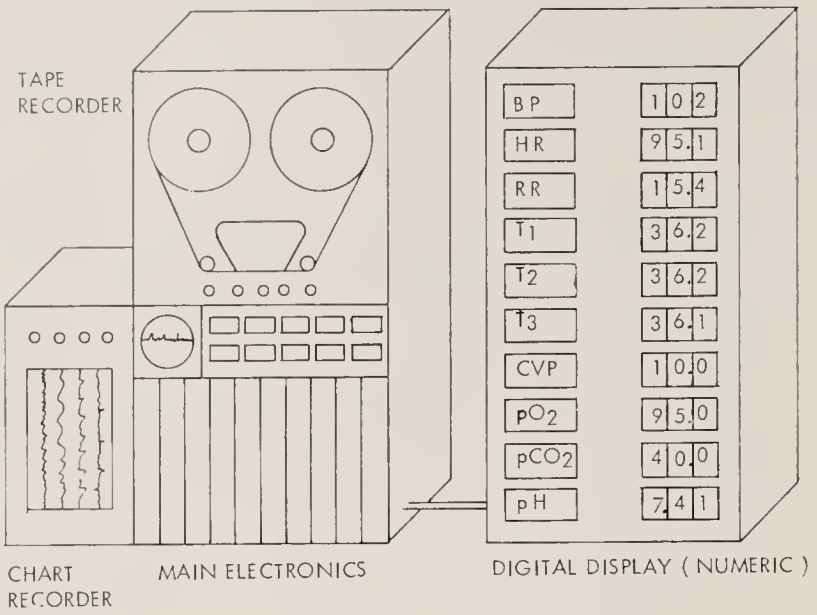

FIG. 2.

There are very few hospitals which have not acquired equipment to monitor the physiological parameters of at least a few patients. Generally, the first areas to be instrumented are the operating rooms and intensive care wards, and later, funds permitting, coronary care units are set up.

Discussion can best begin with the simplest of the three variants of physiological monitoring, individual instrumentation. A typical unit is shown in Fig. 1. Included in this monitor are an oscilloscope for visualizing electrocardiogram (EKG) wave forms, analog meters for registering various physiological values, and electronic modules (signal conditioners) which allow the aforementioned displays to function. The traditional temperature, pulse rate, respiratory rate, and blood pressure are shown. Other physiological variables could equally well be provided if desired. In many units, alarms are available in the form of lights, or buzzers, for signaling that pre-set limits have been exceeded.

Three basic electronic building blocks comprise the typical monitor of Figure 1: Transducer, Signal Conditioner, Display device. A temperature channel might be described. The transducer is a device which converts a physical measurement into an electrical voltage. In this particular example the transducer would be a thermocouple, with an output voltage in the millivolt range. A signal conditioner is required to amplify the transducer output voltage to a level high enough to drive display devices (meters, oscilloscopes, chart recorders) or to interface with a computer. It should be stressed that in many instances the signal conditioner may perform more than just an amplifying function. For example in heart rate, or respiratory rate signal conditioners, the electronics in the conditioner provides amplification, and wave-shaping and counting functions as well.

In the operating theatre, a monitoring unit is used which is not unlike the basic ward unit of Figure 1, but it is made more flexible by having additional physiology parameter channels, and more sophisticated display and recording devices. In Figure 2 this expanded system is shown. Along with the extra variables illustrated, many O/R's are now incorporating such complex measurements as cardiac output (Fick Method), inhalant gas mixture, disconnect alarms, base excess, respiratory flow rate, and numerous pump-oxygenator measurements. The more complex the surgery performed, the greater the number of measured parameters. To make visualization of rows of meters easier, the more sophisticated monitoring equipment includes digital numeric display readouts. The tape and chart recorders provide greater flexibility in recording events for later recall or analysis.

The second or "system" approach, is a considerably more expensive proposition, and is not extensively employed at the present time. In this type of system, all the patients in a ward (intensive care or coronary care units) are monitored, and their respective signals are routed by some transmission system to a central display area. At the central area one or several nurses can monitor the entire group. This type of system is illustrated in Figure 3. There are many advantages and disadvantages to a system like this. On the plus side it is obvious that electronics remove the drudgery of gathering and recording parameter data, allow a few nurses to do the work of many, and at the same time

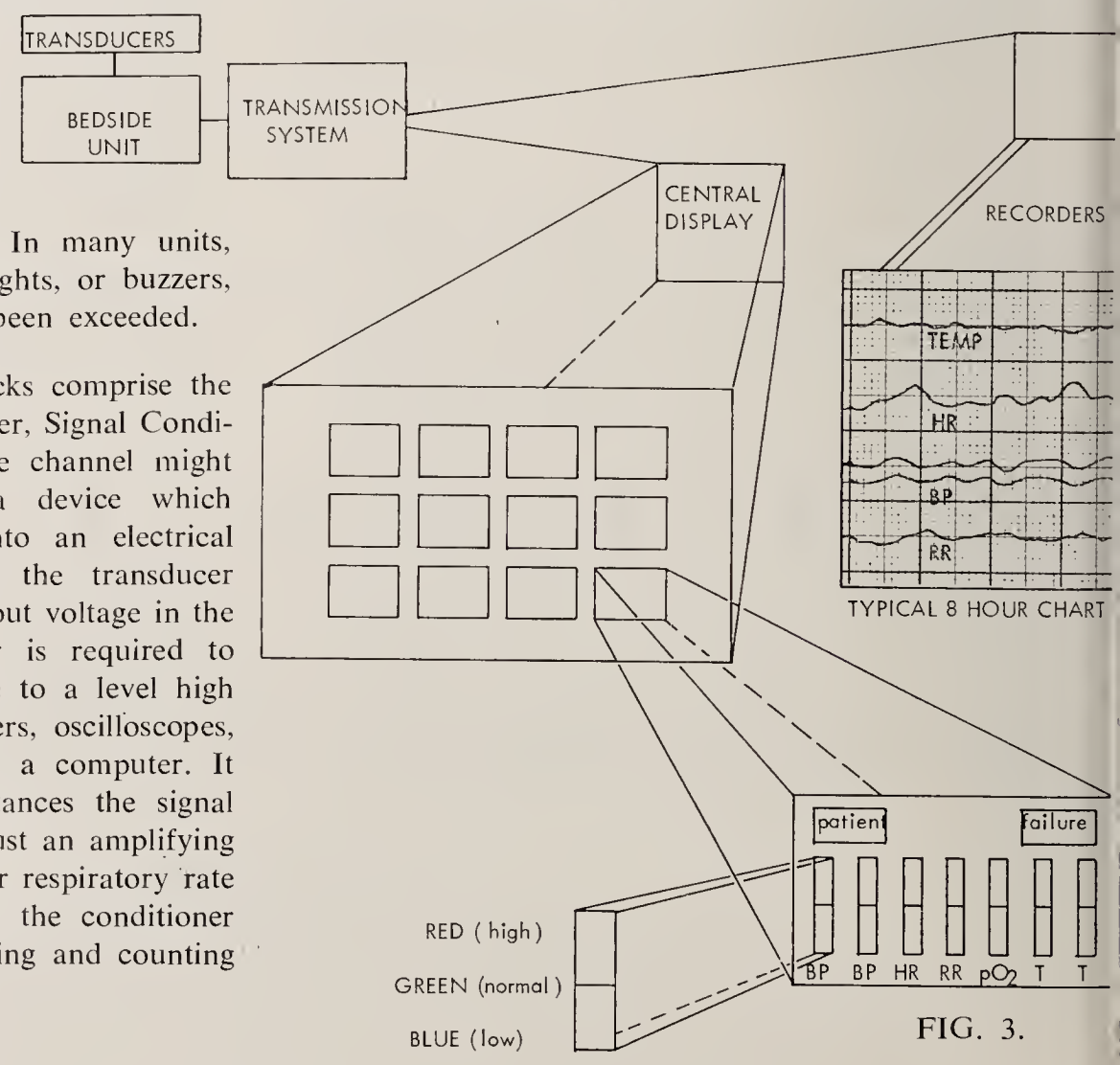

FIG. 3.

obtain better vigilance and care. These considerations are of particular importance in the smaller centres where nursing personnel are difficult to come by. On the negative side the expense is great, and redundancy occurs in the availability of monitored data at both bedside and central monitoring station. There is also a maintenance consideration, but this is becoming less important with the increasing reliability of micro-electronic circuitry.

Looking at Figure 3, the transmission system is the next component requiring elaboration. Most patients who require electronic monitoring are kept at complete bed rest, or bed rest and bedside commode privileges. Ideally, transmission of their data by radio frequency (R.F. telemetry) would allow them the least discomfort caused by electrode wires, and associated transducers, but this is prohabitively expensive. Thus, the cheapest and most reliable method of direct wiring is most widely used.

At the central monitoring station, all the wiring from the ward terminates. Here one finds a large display panel with many individual panel segments, each segment representing a group of signals derived from one patient. The signals are displayed on very simple meters which register only that the parameter indicated is within limits, or exceeds them. All physiological parameters are normalized by the signal conditioning electronics at the bedside. This means that regardless of the output voltage at the transducer, the signal voltages which arrive at the display panels will all cause identical deflections if none is abnormal. Thus, for a set of normal readings from some particular patient, the needles on all the meters will be at the same level. In this way a deviation of one parameter becomes *immediately* apparent. Once again, alarms are incorporated in this type of system as in the first. In any system of instrumentation incorporating alarms, the observer's (nurse's) responsibility resides primarily in assessing the status of a patient relative to the parameter limits denoted by the physician.

Since this journal is devoted to computers in medicine, the third type of patient monitoring should receive the majority of discussion. However, because the third type is just a variation on one and two, the previous groundwork was prerequisite. This recent area of endeavour is by far the most costly and complex, consequently only a few experimental systems have become operational to date. However, the most exciting work is coming from this activity, and there is no area in mechanized medicine which holds so much promise for the future.

When a computer is added to systems of type one or two, the electrical signals arriving from bedside units or a central monitoring station cannot be immediately entered into the computer. Modifications must first occur so that the electrical voltage variations caused by physiological parameters are converted into a form compatible with the computer.

The Multiplexor and Analog-to-Digital Converter are the devices required to perform this "matching" or "interfacing" function. It must appear quite puzzling to those unfamiliar with computers as to how the machine can process waveforms, let alone numerical data. If one remembers that the computer can only process groups of pulses or digits, the whole discussion should be more understandable. By some means the wave-forms interfacing with the computer must be converted into trains of pulses. Because multiple signals eminate from the monitoring units, a means of scanning these signals one-by-one is required as well. The *multiplexor* is just such a device. A multiplexor is an extremely high speed switch which looks at input signals sequentially for an instant at a time. Each time it looks at one of the inputs, it takes a sample, and passes this sample on to the *analog-to-digital converter* (ADC). The ADC takes this piece of sampled data (still a voltage level) and converts it into a digital number. The digital number is represented by a train of pulses in the computer called a binary pulse train. It is this final format which is used from then on inside the computer. The actual multiplexing and conversion process is considerably more complex than has been described; suffice to say that physiological waveforms enter the multiplexor-converter in analog form, and leave in computer-compatible binary format.

Although patient monitoring equipment has been around now for five years or more, the addition of computers to the monitoring equipment is a very recent advance. As a result, only a few patients at a time have been put "on-line", while new methods and problems were worked out. We are still in the developing stage, and therefore all of the present activity in this field is rightly termed research. It is important to note that once a computerized monitoring system has been "debugged" for a few patients, expansion to the monitoring of multiple patient loads is not at all formidable, as the same computer programs are used.

It was a logical step to apply computers to physiological monitoring equipment, because of the vast quantity of data involved. In the first attempts, the physiological data was routed to the computer, and the machine accumulated, correlated, and then presented printed copies of all the variables measured, and their respective values. It rapidly became apparent that simple "data-logging" generated so much printed data that medical personnel would never be able to read and digest the information obtained. Thus, the next step was to program the computer to only perform its monitoring function periodically, and to make assessments on this data and inform the medical personnel of significant changes. Typical of the programmed logic sequence in the computer for this task are the following:

1. Start sampling sequence and take and convert a block of physiological data.
2. Store data in computer memory.
3. Convert data into engineering units (ie: pressure in millimeters of mercury, temperature in degrees centrigrade, heart rate in beats per minute, etc.).
4. Find the average value of each parameter stored (this is a function of the number of samples).
5. Compare these values to stored limits (high and low).
6. If limits were exceeded make note of it.
7. Prepare final summary. Store it in memory.
8. Print summary with deviations from limits marked in red.

It must be stressed that the actual programming has a considerably greater number of steps than this, but this is indicative of the kind of flow of commands.

Then, for each of the patients monitored the summary might appear as shown in Table 1.

TABLE 1.

1. Patient Name, location, number
2. Date, time interval this summary represents
3. Heart Rate: a) Mean
   b) Maximum
   c) Minimum
   d) Standard Deviation
   e) Variance
4. Respiration Rate with same list
5. Temperature Rate with same list
6. Blood Pressure with same list
7. Patient activity level or status

It must be stressed that the type of results which are obtained with these computerized systems are tremendously variable and depend entirely on the objectives and area of application chosen by the principal investigator.

A brief description of one facility which is presently operational can serve to give the reader a closer look at what is currently available. The type of patients monitored are generally post-operative open-heart surgery cases who are instrumented with some or all of the following.

1. Indwelling catheters for direct blood pressure measurement
2. EKG leads
3. Respirator
4. Temperature transducers

These allow the following primary data to be continuously collected by the system: EKG, venous and arterial blood pressures, respiratory flow and pressure, respiratory partial oxygen and carbon dioxide. Patient body temperatures are read periodically by the system. Partial oxygen and carbon dioxide pressures, pH, and hematocrits are measured manually by the lab technician, and this data is entered into the computer by a typewriter at the ward nursing station, or some other location.

Variables generated by this type of system are sometimes classified into three groups.

a) *Primary variables (or parameters)* are the physiological measurements the transducers pick up.

b) *Secondary variables* result from computations performed "on-line" by either analog pre-processing, or the digital computer. (On-line means at the same time the measurements are occurring). An example is heart rate. This can be extracted from the EKG, by either the signal conditioner (analog pre-processing) or by a digital computer program.

c) *Tertiary variables* consist of trends, variances, time series analyses such as auto and cross-correlations, Fourier analyses, and power spectral densities. All of these statistical analyses require considerable computing power, and at the present time this type of data is usually processed off-line. More sophisticated real-time facilities are beginning to incorporate tertiary subroutines in their programming.

In the system presently discussed the following patient parameters (primary variables) are monitored continuously by the system for abnormal or alarm conditions: average heart rate, instantaneous heart rate, EKG artifact, average pulse rate, instantaneous pulse rate, average arterial blood pressure, instantaneous arterial blood pressure, respiratory pressure.

Patient parameters (secondary variables) which are periodically calculated for display purposes and for the history file are: temperatures, heart rate, pulse rate, pulse deficit, premature beat rate, average arterial and venous pressure, arterial pressure first derivative (rate of change), relative stroke volume, tidal volume, respiratory work, lung compliance, oxygen uptake, respiratory quotient, and Fick cardiac output.

In Figure 4 a photograph of the computer control room is shown. In the three cabinets at the left are

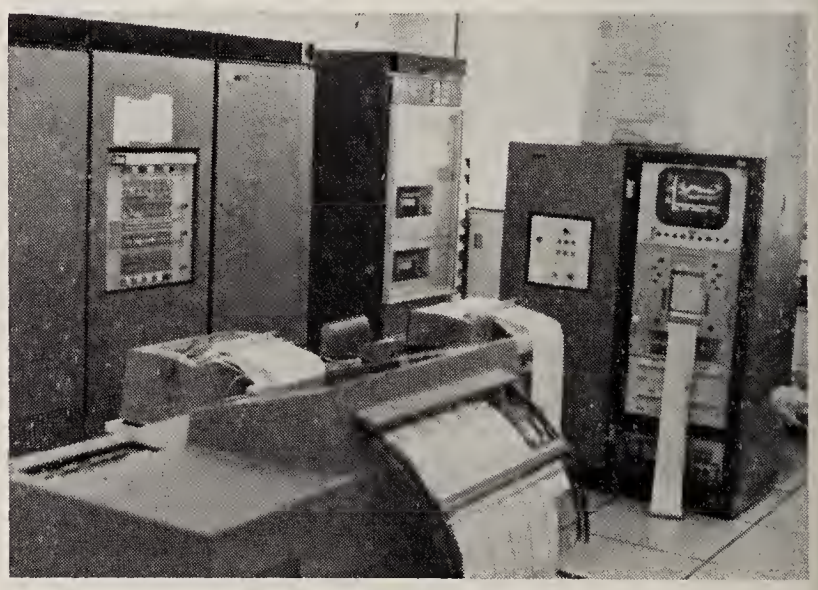

FIG. 4.

housed the computer per se, and the multiplexor-converter electronics where the remote physiological signals terminate. The two cabinets at the right contain the electronics for the cathode-ray alpha numeric display. The system operators can call up just about any type of data format desired on this device. For example, one can request a summary table of the patient's secondary variables for the past four hours, or a graph of one (or several) primary or secondary variables versus time for that same time interval. The large cabinet in the background of Figure 4 contains a one and one-half million "word" magnetic disk memory. It is because of this type of memory capacity that the computer can be requested to use past data for making summaries or graphs. The storage of data is not infinite, and data which is more than a certain "age" is erased to make room for new.

In this type of system, then, not all data is stored in memory or printed for permanent records. Only periodic summaries are generated, and these are printed out automatically, once every hour. If summaries are desired more frequently, the system operators, or physicians at remote nursing stations, can request them.

In the foreground of Figure 4, an automatic line printer, a teleprinter, and a typewriter are seen. It is by these means that human operators carry on their communication with the computer. The physiological data enters by a separate route (the multi-plexor converter interface.) The operators, however, can ask the computer to use this physiological data in any way they deem necessary at a particular moment. If no specific display or print-out formats are requested, the computer will continue to periodically produce the routine summaries previously mentioned. If the computer utilized in the system is a powerful one (a machine usually of large core, and bulk memory capacity), and its repertoire of statistical subroutines considerable, the operators can request extensive additional information from the raw data flowing in. For large volume information outputs, the computer will probably use the line printer. For short messages to and from the computer, typewriter and teleprinter are used respectively. Although most requests to the computer are entered by keyboard (typewriter), data may also be entered by switches on the control panel of the central processor, shown in the middle left cabinet of Figure 4.

Before leaving the discussion of this exemplary system the type of secondary calculations, and why they might be required, merits mention. One might question, for example, why such a variable as lung compliance would be computed? Often in post-operative surgical cases pleural effusions or atelectasis develop. In the past, x-rays were taken serially at periodic intervals to keep tabs on this, but recent studies have shown that lung compliance is decreased before there are x-ray or clinical signs of effusion. There is a similar rationale for all of the other parameters mentioned earlier. Because the computer can calculate these datum with untiring rapidity, man has unquestionably acquired a powerful sensory extension for clinical evaluation.

It must be added, that many types of data which are now available have not been discussed. Systems are presently in operation where acid, base, fluid and electrolyte calculations are machine—provided for clinicians dealing with patients in shock. This allows the physician to titrate immediate patient requirements against continuing computations of the response to therapy. Even higher levels of complexity are being approached in systems where the computer itself controls the therapeutic titration, free from the "lag" introduced by human involvement.

In coronary care units, the emphasis is on continuous ECG analysis, and many of the other signals are not required. Changes are detected very rapidly because a complete analysis can be computed and documented in seconds. This topic is further discussed in Mr. J. McElroy's article.

Systems are presently being developed wherein the computer is used to monitor patients on hemodialysis units, and the control of the dialysis is being assumed by the machine.

One might get the feeling after reading this journal, that in the near future, every patient entering the hospital will just be hooked up to the machines, and the diagnosis and therapy will pop out some chute in the doctors lounge! A word of caution is urgently required. Just as one must tailor drugs or other treatment that a patient receives to that patient's individual needs, so must we tailor monitoring to those parameters which will result in each patient's greatest benefit. The decision to use extensive monitoring facilities must be based on the value of the information derived, and the practicality of obtaining the information. Not every patient requires an SGOT, or a culture and sensitivity on his or her blood. So it is with monitoring. There is no justification for continual respiratory monitoring in a patient with myocardial infarction. A patient who has had a pheochromocytoma removed, however, might well merit blood pressure monitoring for several days postoperatively.

Not every patient in a hospital requires continuous monitoring of all vital signs. There are patients, however, whose lives will depend on the type of advanced information these systems can offer. We do both patients, and medicine, a disservice, if present day medical technology is not applied to situations where it is warranted.

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Diagnostic Procedures - The Trend Toward Multiphase Screening Tests

D. J. Shepley, B.A.Sc., M.D. *

INTRODUCTION

Physicians of earlier times were limited to the use of their unaided senses in arriving at a clinical impression which would form the basis for their treatment. Over the intervening years the advances of science and technology have been cautiously applied in the field of medicine to extend the physicians's senses such that he is now able to "see" where he could not before, and act decisively on information not available before.

What are these "extensions"? I refer here to any and all diagnostic procedures which have developed within branches of medicine now called:

Radiology—eg: chest X-ray, G.I. series
Haematology—eg: Hb, WBC, smear, diff.
Biochemistry—eg: Na, K, Cl, Ca, P determinations
Bacteriology—eg: identification of bacteria and their sensitivities to antibiotics
Virology—eg: identification of viruses
Pathology—eg: examination of mieroscopic sections
Cardiology—eg: ECG
Neurology—eg: EEG
Ophthalmology—eg: acuity tests, tonometry
Otolaryngology—eg: audiometry (subjective and cortical)
Psychiatry—eg: psychological tests such as personality inventories

to mention but a few.

PROBLEMS

Clinicians accepting the value and necessity of these "extensions" are demanding more and more investigations as a part of the diagnosis and treatment for their patients. This is shown dramatically by the 15-20 per cent increase per annum of the investigations carried out in the laboratories across the country. This trend is likely to continue and could even accelerate for there has been an increase in patient turnover in most hospitals, an increase in the number of tests performed on each patient, an increase in the number of patients having tests, an increase in the number of new tests which are being constantly introduced, and an increase in Out-Patients' investigations. It can readily be seen, then, that a major problem is that of VOLUME. This compounds the problem of obtaining adequate staff and adequate facilities. Further compounding this problem is the fact that in many instances especially in highly populated areas, all the hospitals are attempting to provide facilities and personnel to do all tests *on site* for the patients of that hospital. This often ends up necessitating the placement of a full complement of trained personnel and equipment at each hospital. However, these trained personnel may end up spending a great portion of their time doing routine tests rather than the special tests which they were trained to do. This then causes both personnel and equipment to be used inefficiently.

Although these are probably the most pressing problems, other trouble areas are present within the laboratories themselves. For instance:

1. How accurate are the tests themselves?
2. How variable are the interpretations of the results?
3. What is the norm?
4. How accurate are the machines in question?
5. How easily and smoothly are "stats" handled?
6. How smoothly does information flow to and from the laboratory?

Further, and not to be forgotten, there is the problem of costs involved for these tests, not only in dollars per test, but risk and discomfort to the patient, as well as in time. Let me elaborate. In most hospitals the junior medical staff who examine patients on admission request tests appropriate to a provisional diagnosis and sometimes add some "screening" tests which examine the function of various physiological systems (eg: BUN, Hb are common screening tests). Further, tests may be requested later by more senior medical staff following their own clinical examination. When the results of all these preliminary tests return to the wards further tests are often needed. This process usually takes several days and may require multiple specimens to be taken from the patient, all adding up to more time and more patient discomfort. In addition, the test to uncover the *real* abnormality may in fact not have been ordered.

Finally, the clerical work the technician must do, is itself compounding the volume problem for the technician must, to mention a few of her clerical duties, identify the specimen, calculate results, and transcribe them onto result sheets.

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* Dr. Shepley, a graduate in both Electrical Engineering. 1961, and Medicine, 1965, interned at St. Michael's Hospital, then spent just over a year with the Medical Team of IBM. Recently, he moved to the Hospital For Sick Children where he accepted the responsibility of Director of Medical Engineering and Computer Services.

These are but a few of the problems met in getting reliable diagnostic test results where they are needed, efficiently.

SOLUTIONS AND TRENDS

To begin to counteract problems like those outlined, laboratories have been implementing more and more automatic equipment to help existing staff and accommodations handle the increasing volumes demanded of them. For instance, more spectrophotometers and more autoanalyzers are being implemented in laboratories across the country.

The next step has been to further expand their capacity by tying these and other such instruments into Data Acquisition Systems or Data Processing Systems such as has been done in Youngstown, Ohio[1], Upsula, Sweden, and Kings County Laboratories, New York. Here the computers have, in addition to expanding their capacity to handle greater volumes, reduced the clerical effort demanded of the technician and streamlined the flow of paper or information.

Automatic equipment and computers alone cannot completely solve the problems of volume, etc. discussed above. However, they do make possible the handling of multiphase screening tests not only within a sick population but a well population also, as witnessed by the work being carried out in the Queen Elizabeth Hospital, Bermingham, England[2], and by the Permanente Medical Group, Oakland, California[3]. At the Queen Elizabeth Hospital they are implementing a plan where twenty biochemical tests are being performed on all newly admitted patients. The Permanente Group has set up an automated multitest laboratory which handles 4,000 patients per month within a 40 hour week schedule passing each patient through a twenty step procedure in approximately two to three hours. There they perform such tests as: ECG, Anthropometry, Chest and Breast X-rays, Visual Acuity Tests, Tonometry, Retinal Photography, Audiometry, Vital Capacity Determinations, Health Questionnaire on Prepunched cards, Eight Blood Chemistries done simultaneously with direct punched-card output.

This information is summarized and printed out by computer to form a report which is assessed by the physician when he sees the patient. The physician then initiates any further follow up procedures he deems necessary.

ADVANTAGES

Many of the advantages of automatic equipment, computers, and multiphase tests have already been implied. For instance, their implementation definitely eases the problems of high volume, staff, facilities and duplication of effort. Further, the use of computers reduces the clerical effort demanded of the technician, provides for better quality control as well as a smoother flow of information to and from the laboratory.

Multiphase tests provide several other advantages. As alluded to before, if multitests were carried out, time and patient discomfort can be measurably decreased. In addition, it is becoming evident with automated equipment that the cost for a battery of tests is actually cheaper than that of one test alone.[4]

Further if multiphase tests are carried out on a well population and a sick population true norms may be established. By carrying out multiphase tests in the key populations such as those in the homes for the aged, those working under questionably unhealthy conditions, abnormalities may be picked up far earlier and indeed in time to take corrective action. This then leads us to another point—What is the cost of *not* doing multiphase screening tests on these key populations? It is possible that there is in fact much sickness and productive time lost due to ill health which might be prevented.

CONCLUSION

Some problems associated with diagnostic procedures can be tackled through the use of automatic equipment, computers, and multiphase screening techniques. Through these facilities the physician of tomorrow will be able to "extend" his senses even further to see and understand more thoroughly the disease processes and act sooner to correct them.

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Computers In Medical Education

P. Levy 7T0

Today we are approaching a crossroads in medical education. The number of students in our medical schools is rapidly increasing; in a few years the number of able teaching staff available will not be able to cope with the growing population of students. Classes will grow larger and larger; student-teacher contact will grow smaller and smaller. Of those who look to the future and see the impending crisis, many are turning to computers as a possible answer to this problem.

In order to gain an understanding of how computers can play a role in medical education, let us look in on a medical student who is attending a computer-taught session. The student is seated at a desk in a small room. On the desk is an electric typewriter, a television (oscilloscope) screen, and other mechanical devices.

COMPUTER: (via the typewriter, the keys of which are being electrically depressed at a speed of several words per second): Please type your name and the date.

STUDENT: (typing on the same typewriter): JOHN SMITH. SEPT. 15, 1970.

COMPUTER: What would you like to study today? (Please type the course number as listed in your catalogue.)

STUDENT: 70120-1.

COMPUTER: Very good. You are interested in "An Introduction to the Use of the Computer as a Tool in Medical Education." As you no doubt have read in your catalogue, this course is intended to explain:

1) The ways in which computers can be used to teach medical students.
2) The equipment involved.
3) How the computer becomes a tool for your education (programming).
4) The advantages and disadvantages of computerized teaching.
5) The extent to which computers will aid in your medical education.

Are there any questions before I present the course format?

STUDENT: NO.

COMPUTER: Fine. Here is how we will proceed. You may ask me any questions you wish concerning the topic. If you like, you may base your questions on the five headings listed above, and you can branch off from these to further questions. In some cases I may have to ask you to reword your question in order that I can recognize the words or the gist of your question. In other cases I may not be prepared to answer your question, in which case I will inform you of that fact, and will store the question in order to present it to the author of this course, who will be happy to supply a reply which I will relate to you at your next session. Please begin your questioning.

STUDENT: IN WHAT WAYS CAN COMPUTERS BE USED TO TEACH MEDICAL STUDENTS?

COMPUTER: There are two main computer set-ups that are being developed to teach medical students:

1) The computer-tutor.

2) The computer-patient.

The computer-tutor acts like the traditional Oxford tutor—presenting information, asking questions, receiving and analyzing replies, and responding to the replies by scolding careless errors, explaining legitimate pitfalls, or complimenting good replies. The computer-tutor will be a widely used device in almost all university courses—not just medicine—and will be capable of teaching all subjects now handled in lectures.

The second device, the computer-patient, is a man-like robot that can mimic various disease states, and is therefore very useful in practicing many clinical aspects of medicine — physical examination, minor surgical techniques, and anesthesiological techniques. Does the type of session in which you are now participating fall into the category of one of the two computer set-ups mentioned above?

STUDENT: YES. THIS SESSION SEEMS TO BE A COMPUTER-TUTOR SET-UP.

COMPUTER: Absolutely correct. This, in fact, is a computer-tutor set-up modified so that you ask most of the questions, and I provide information about the subject in the form of my answers. Please continue with your questions.

STUDENT: WILL THE COMPUTER-TUTOR SET-UP JUST INVOLVE THE TYPEWRITER, OR WILL THE TELEVISION SCREEN WHICH I SEE BEFORE ME BE INVOLVED ALSO?

COMPUTER: Let me describe to you the equipment involved in a typical session: You sit in one of many small rooms containing a desk with a typewriter, oscilloscope screen, earphones and a microphone. These devices are the means of communication between you and the computer, just as the receiver of a

telephone is the means of communication between you and a distant caller. The actual computer may be a few feet, or many miles, away.

At present the typewriter is the most commonly used means of communication by the computer and by the student. However, the oscilloscope screen is an important accessory for communicating to you any visually-orientated information — diagrams, motion pictures, histology slides, graphs, and so on. You, in turn, can use the oscilloscope to communicate information back to the computer. This is done by drawing on the screen with a special pencil. In this way you can answer questions that involve pointing out particular areas on a diagram or slide, or drawing a particular curve on a graph. Finally, the earphones and microphone are important in auditory communication—pronunciation of new words, learning heart sounds, and so on. As computer technology progresses, auditory communication may take over more and more of the role of the typewriter. Even now, computers have been developed that operate through spoken conversations between operator and machine. Through these devices, information is supplied, questions are asked, and responses are made. In presenting information, the oscilloscope screen, the typewriter and the sound equipment are extensions of the computer that can be said to correspond to the chalk-wielding hand and the voice of a professor or tutor; in receiving replies from the student, these extensions of the computer act like the professor's ..... and .....

STUDENT: EYES AND EARS.

COMPUTER: Good. Please proceed.

STUDENT: TO TAKE YOUR ANALOGY ONE STEP FURTHER, WHAT IS THERE IN THE COMPUTER THAT ENABLES IT TO CORRESPOND TO THE PROFESSOR'S BRAIN?

COMPUTER: Would you please rephrase your question.

STUDENT: THE COMPUTER YOU DESCRIBE SEEMS TO HAVE A STORE OF KNOWLEDGE, FOR IT CAN PRESENT INFORMATION, BUT IT ALSO SEEMS TO KNOW WHEN TO CALL UP CERTAIN PIECES OF INFORMATION, (IN RESPONSE TO A STUDENT'S PARTICULAR QUESTION), RATHER THAN JUST REGURGITATING ITS INFORMATION AS A TAPE RECORDER WOULD DO. FURTHERMORE, YOU CLAIM IT CAN COMMENT ON STUDENTS' VARYING RESPONSES, BE THEY RIGHT OR WRONG. HOW DOES THIS MACHINE COME TO HAVE THESE ATTRIBUTES OF HUMAN INTELLIGENCE? THAT IS, HOW CAN A MACHINE BE DESIGNED TO ACT LIKE A TEACHER CARRYING ON A DIALOGUE WITH A STUDENT?

COMPUTER: I believe you wish to know the answer to the third area of discussion which I proposed at the beginning, that is, "How does the computer become a tool for your education?" Was this the essence of your question?

STUDENT: YES.

COMPUTER: Good. I must state, from the very beginning that the computer has no mysterious intelligence of its own. Everything it does is a response that has been built into its mechanisms (programmed into it) by the dictates of the person who is the author of the course. It is the author who determines *what* the computer will say, and *when*, (that is, on what cue words), it should say it.

Only skilful planning on the part of the author can make a computer a truly effective tutor. The author must not only supply the information and give pertinent questions and answers, he must also anticipate the various errors a student might commit, and then compose replies to these that will encourage the student to discover and understand the correct answer.

Through the author's planning, an apparently spontaneous dialogue develops between the student and the computer. The teaching proceeds by having the dialogue progress from one piece of information, one frame as it is called, to the next, more advanced frame. When a student answers a question correctly, the computer acknowledges the answer and proceeds to the next frame in the course. An incorrect answer would cause the computer, like any tutor, to point out the error and provide further explanations. A different incorrect answer, to the same question, would cause the computer to provide a different explanation aimed at the particular error involved. The computer would not advance to the next frame until the correct response is made.

Thus, you can see that the computer is made into an effective tutor by providing it with sets of responses and explanations that correspond to a real tutor's set of replies. These sets of responses make it possible to have realistic computer-student dialogues.

It is interesting to note that the achievement of realistic dialogues depends largely on the cleverness and imagination of the author in anticipating all the various directions in which the conversations might go.

STUDENT: WHO WILL BE THE AUTHORS OF COMPUTER COURSES IN MEDICINE?

COMPUTER: The author of any medical course will be a professor of that subject. Just as in the case of

textbooks, one gifted professor could organize a course that could be used at many medical schools. Not every professor need be a talented program author.

It is interesting to note further that the author does not need to know any of the coded mathematical language of the computer. Professional programmers can translate the written course into the computer language, which is then fed into the machine.

STUDENT: WHAT PARTS OF THE MEDICAL COURSE CAN BE COMPUTER TAUGHT?

COMPUTER: 1) All subjects which are now handled in lectures can be computer taught. The method would be the type described above—presentation of information, asking of questions, and so on.

2) The techniques of diagnosis can be computer taught. In the past, the learning of this important aspect of medical education has been largely dependent on having a good clinician whose methods the students could imitate. However, the clinician does not have time to guide all his students in their efforts at diagnostic reasoning. Today, those in the computer industry who are planning applications of the computer to medical education are especially interested in developing this aspect.

A computer session designed to give practice and guidance in diagnostic skills would proceed in the following way: The various details of the patient's history, his physical examination, and laboratory results would be supplied by the computer, but only as each bit of information is requested by the student in an organized manner. The student is asked to suggest tentative diagnoses, and to describe his management of the case. The computer will report on how the patient is progressing under the student's management. In order to simulate a true-to-life situation, various day-to-day contingencies, like delays in receiving laboratory results, are programmed into the course. Throughout the entire session, the computer, acting as tutor, will comment on each step taken by the student in his investigation and his deduction of the diagnosis. In this way, the student gets immediate and individualized guidance in his attempts at solving and managing a particular case.

STUDENT: YOU MENTIONED THE COMPUTER-PATIENT BEFORE. I WONDER HOW AUTHENTIC SUCH A ROBOT CAN BE. CAN IT REALLY BE USEFUL?

COMPUTER: A computer-patient has been developed at the University of Southern California School of Medicine for use in its anesthesiology department. It is a life-size model, covered with a plastic that looks and feels like real skin. It has a tongue, vocal cords, esophageal and tracheal openings, bronchial tubes, a heartbeat, carotid and temporal pulse-beats, and blood pressure. Its chest and diaphragm move as it breathes. Its eyes can open and close, and the pupils react to light. It even wrinkles its eyebrows. The robot is able to react to several different drugs injected into it, and to certain anesthetizing gases. It can simulate almost all physiological conditions that the anesthesiologist might encounter during an operation. An instructor seated at a nearby control panel can alter the robot's condition to mimic cardiac arrest, shock and adverse drug reactions. The student must treat the emergency condition as he would in a true life situation. In this way, months of a student's operating room experience, previously at the expense of real patients, can be replaced by a few days of intensive multi-situational training using such a robot.

STUDENT: WHAT ADVANTAGES DOES COMPUTERIZED TEACHING, ESPECIALLY THE USE OF THE COMPUTER-TUTOR, HAVE OVER THE PRESENT TEACHING SYSTEM?

COMPUTER: The advantages are numerous:

1) There is *individualized* teaching. The computer stops to explain those points which the particular student does not fully understand, (as evidenced by his responses), before proceeding to more advanced items. Occasionally a perceptive professor will notice quizzical looks on his students' faces and will clarify his point; but, often only a few students will miss the point, and a professor, in contrast to a computer, cannot be expected to clarify each item for each student.

2) It is an *active* process requiring constant attention on the part of the student. Computerized courses involve frequent responses from the student—responses that require an understanding of the previously presented information. The lecture system, by way of contrast, too often involves the passive transfer of information from professor's mouth to student's notepaper, while actual understanding of the material is postponed, or worse still, replaced by mere memorization.

3) The student proceeds *at his own rate.* Items that are understood, (as evidenced by a student's correct responses), are not belaboured—the course proceeds to the next level. Points that are not fully understood are explained further. Thus, the fast learner is not held back, and the slow learner is not overwhelmed by a mass of facts that he does not understand.

Note: These first three advantages are related to the fact that the computer acts as a personal tutor.

4) The student's progress is *constantly evaluated.* The student's responses, his amount of delay before answering (which is measured by a timing device built into the computer), and the amount of extra explanation he requires are recorded by the computer.

The professor can, at any time, elicit this information from the computer's memory. Furthermore, the computer can be programmed to automatically notify the professor if any student is falling far behind; thus, the professor need not waste time constantly reading each student's progress reports. Instead, he can spend more time with the students who need his personal help. It can be seen that constant evaluation by the computer will help to minimize the need for, and importance of, major examinations.

5) *Examination* of a student's overall knowledge and understanding of a course will follow the same tutorial-type format as the rest of the course. The student will receive the usual immediate response from the computer concerning the correctness or incorrectness of his answers. Such immediate response, or feedback, is one of the ideal conditions for any learning process; thus, examinations of this sort are ideal, in that they not only inform professor and student concerning the student's progress, but are also a learning experience for the student.

6) The programming of a course necessitates that it be organized in a *logical* step-by-step form, which is, of course, a great advantage not always achieved in lectures.

7) Since one author's course can be used in many medical schools, there will be a *greater uniformity* in the calibre of medical education than now exists.

8) The course material and methods of presentation are carefully evaluated by the computer. Students' responses (number of correct and incorrect replies to a particular question) can be used by the computer to evaluate whether the material is consistent and is presented in an understandable way.

9) *Course material can be easily updated.* When new advances are made, or when deficiencies in material presentation become apparent, the author of the course can extract undesired portions of the program and add new material. The computerized course is therefore flexible—more like a good teacher than like a textbook.

10) There is *no limitation concerning the time* of day when instruction is carried out. Conceivably, the computer could be made available in the evenings and on weekends, as well as the usual school hours. This would be a direct contrast to the rigidity of the lecture schedule.

11) Professors will have more time to spend on research and private counselling, rather than on preparation and presentation of lecture material.
You can see that there are quite a few advantages associated with computerized teaching.

STUDENT: YES, I AGREE. NOW CAN YOU TELL ME WHAT DISADVANTAGES ARE INVOLVED IN COMPUTERIZED TEACHING?

COMPUTER: Can you suggest any?

STUDENT: IT SEEMS THAT IT COULD BE IMPERSONAL.

COMPUTER: True, it is impersonal compared to having a real private tutor. However, it is much more personal than attending a lecture with over one hundred other students.
Any other suggestions?

STUDENT: IT SEEMS TO ME THAT THE CONVERSATIONS WILL BE MECHANICAL AND UNNATURAL.

COMPUTER: I agree with you to some degree. In the initial stages of developing computer-student dialogues, the conversations may not run smoothly. The computer may lose track of your train of thought, or may be unable to answer your questions. The computer can never be as versatile in its range of responses as a human tutor, though it can build up a large repetoire.
Any other suggestions?

STUDENT: NO, I CAN'T THINK OF ANY AT THE MOMENT.

COMPUTER: I can add one. To achieve the most convenient scheduling of student's courses, medical schools will have to obtain a very large number of individual tutorial compartments. In an ideal set-up, each student will have his own compartment with oscilloscope, typewriter, and acoustic equipment, and he can use it whenever he wishes. These compartments will all be linked to the one or more computers that contain the courses. It is a very big project, but I think it is worth it, don't you?

STUDENT: YES.

COMPUTER: Have you any further questions?

STUDENT: WILL COMPUTER-TAUGHT MEDICAL EDUCATION ACTUALLY BE VERY DIFFERENT FROM THE PRESENT SYSTEM, FROM THE STUDENT'S POINT OF VIEW?

COMPUTER: Not very different. The time presently being spent in lectures will hopefully be much more productively spent attending computer-tutored courses. However, studying and reading on your own will still be the key to your education. The active participation demanded in a computer-taught session will necessitate day-by-day home study to complement the sessions.

STUDENT: CAN I SKIP MY COMPUTER SESSIONS, JUST AS I SOMETIMES SKIP MY LECTURES?

COMPUTER: When you don't feel inclined to go to a session, you don't go. When you feel like going,

you go. This you can do without missing any sessions, since (if the school has enough tutorial units) there will be no set time schedule dictating what time of day you must attend sessions. It would be foolish, however, to actually skip the sessions of your course. No one can learn everything there is to know in the field of medicine, and therefore these courses are designed to emphasize the important areas on which the student should concentrate.

STUDENT: WHAT IS YOUR OVERALL OPINION OF THE USE OF COMPUTERS IN MEDICAL EDUCATION ?

COMPUTER: Let me ask *you* that question.

STUDENT: WELL, I WOULD SAY THAT COMPUTERS WILL ENABLE MEDICAL STUDENTS TO GAIN THE ADVANTAGE OF INDIVIDUALIZED TEACHING WITHOUT PUTTING AN IMPOSSIBLE STRAIN ON MEDICAL INSTRUCTORS THEMSELVES. THEREFORE, IT SOUNDS LIKE A VERY GOOD IDEA.

COMPUTER: I agree. Would you not also say that our man-like robots will provide you with a more humane method of practical training.

STUDENT: YES.

COMPUTER: Have you any further questions.

STUDENT: NO. NOT AT THIS TIME.

COMPUTER: Then we shall call this session to a close. Thank you. We shall see you again soon. I hope you enjoy your future with computers.

FOR FURTHER READING

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Clinicopathological Conference

The Differential Diagnosis Of A Pulsatile Mass In The Left Upper Quadrant

CASE PRESENTATION

First Admission

A 79 year old, white female was admitted to hospital May 5, 1959 for investigation of abdominal pain of 9 weeks duration. The pain occurred nearly every day, and was located in the left upper quadrant radiating to the left lower dorsal and costovertebral areas. It was steady and usually lasted 1 - 5 hours. In addition, the pain often occurred 1½ - 2 hours after eating, and was relieved somewhat by antacids. The patient's appetite had been poor for several weeks prior to admission and she had noted a few pounds weight loss in this time. There was no history of nausea or vomiting, heartburn, belching, flatulence, early satiety, jaundice, or any change in bowel or urinary habits. The remainder of the functional enquiry at this time was negative. Past health included recurrent cystitis in 1939, and a cholycystectomy in 1934. Also, diverticulosis of the colon had been demonstrated radiologically one year prior to admission.

On physical examination the patient appeared healthy, was co-operative, and in no acute distress. Her temperature was 99°F, respiratory rate 16/minute, pulse 75/ minute, and blood pressure 140/90. The liver edge was just palpable on deep inspiration, and was slightly tender. At this time the remainder of the physical examination was unremarkable.

Urinalysis, including bilirubin and microscopic examination was negative. Hemoglobin, WBC, and blood film were normal. An upper gastrointestinal series showed a small oesophageal hiatus hernia but no evidence of ulceration or neoplasm. A barium enema and x-rays of the thoracolumbar spine and chest showed no abnormalities. A right scalene lymph node biopsy revealed no pathological changes. From the history of the patient's pain and the absence of positive findings pointing towards an intraperitoneal lesion, the possibility of a retroperitoneal malignancy was considered. A laparotomy was not performed at this time because of the patient's age, and she was discharged May 29, 1959.

Second Admission (6 months later)

The patient was readmitted to hospital December 18, 1959 still complaining of abdominal pain though somewhat changed in character. The pain was now almost

continuous, crampy, and was located in the left lower quadrant and periumbilical region; it still radiated to the back. Position and movement did not affect the pain, however, it was now aggravated by defecation and urination, and antacids no longer gave relief. The patient's appetite had remained poor and she had lost 20 pounds since her first admission. There was no history of melena or hematemesis but she had vomited green, bilious material about once a week for several weeks prior to admission. Functional enquiry was otherwise negative.

Physical examination revealed an alert, pleasant female in no apparent distress. The temperature was 98°F, the pulse 108/minute, and the blood pressure 170/100. The heart rate was regular except for occasional extrasystoles. A grade I/VI apical systolic murmur and a pericardial friction rub were heard. The abdomen was diffusely tender, most markedly in the lower guadrants. The liver and spleen were palpable on deep inspiration and a questionable mass was also felt deep to the lower splenic border in the left upper quadrant.

Urinalysis, including bilirubin, was still negative. On microscopic examination numerous epithelial cells, 5 - 8 WBC/HPF, and occasional bacteria were noted. Routine blood work was normal. Total plasma protein was 5.6 grams %. X-ray examination of the cervical and lumbar spine, upper gastrointestinal series, and barium enema showed no significant changes. Sigmoidoscopic examination was normal.

The patient's condition remained relatively unchanged until approximately one month following admission. At this time the blood pressure remained about the same at 160/90 but the pulse rate was now variable, ranging between 100 - 120/minute. The pericardial rub was louder and was increased in intensity both on inspiration and when the patient sat up. She felt weak and nauseated, and complained of aching, stiff fingers and leg cramps at night. She also complained of a severe frontal headache of 10 days duration. Bowel movements caused pain across the mid-abdomen, and generalized sweating was apparent early in the morning.

Four months after admission the patient began to improve. At this time steroid therapy was started with marked increase in appetite and strength. The pericardial friction rub had disappeared and the pulse rate had returned to about 80/minute and was regular. The patient was discharged April 9, 1960 with a provisional diagnosis of cancer of the pancreas.

Final Admission (8 months later)

The patient was readmitted to hospital on January 26, 1961 because of continued abdominal pain, and vomiting. The pain was diffuse, colicky, and radiated to both flanks. The nausea and vomiting were associated with severe, continuous diarrhea. She had lost a further 10 pounds since the last admission. She still complained of tender joints and diurnal sweating.

On examination the patient was pale, cachectic and in moderate distress. The pulse rate was 92/minute, with occasional bursts of tachycardia; the blood pressure was still 160/90. No pericardial friction rub or murmur were heard. The abdomen was diffusely tender and the liver was palpable 5 cm. below the right costal margin. The spleen was palpable 3 cm. below the left costal margin but now a large, pulsating mass was felt deep to the spleen and extending into the epigastrium. Over this mass a continuous bruit was heard which was more pronounced in systole. It could not be heard in the back. No ascites or jaundice were present.

Urinalysis showed 2^+ protein and microscopically, there were occasional coarse granular casts, 3 - 4 WBC/HPF, and many bacteria. Routine blood work, including serum electrolytes, remained normal.

Two weeks after admission the patient developed dysphagia and on several occasions regurgitated undigested food into her throat. She also had persistent vomiting, but never hematemesis. She continued to have severe diarrhea and visible peristalsis was often noted. Stools were at no time black or bloody. The pulsating mass had enlarged, now filling the left upper quadrant, and the bruit had extended laterally to the anterior axillary line. The patient's condition continued to deteriorate with nausea, vomiting, weight loss, marked abdominal and back pain, and she suddenly expired February 26, 1961, four weeks after admission. A postmortem examination was carried out.

DIFFERENTIAL DIAGNOSIS

The case history was presented to Dr. L. F. W. Loach, of the Toronto General Hospital, and his discussion of the differential diagnosis follows:

Dr. L. F. W. Loach:

This elderly woman suffered from abdominal pain for 20 months and died a few weeks after a pulsating abdominal mass had become clinically detectable. When she initially presented she localized her pain to the left upper quadrant. The pain did not appear related to the function of abdominal viscera. Diverticulosis of the colon had been identified previously and she had had a cholecystectomy. Physical examination was unremarkable (the tender liver edge is of dubious significance) as was laboratory investigation. Of note, a barium enema and gastrointestinal series were negative.

In older people three disease processes are common: obliterative vascular disease, neoplasia and infection. Because this patient had little disorder of function, because gastrointestinal x-rays were negative, and because urinalysis was unremarkable, her physicians made a provisional diagnosis of retroperitoneal neo-

plasia—a reasonable decision. The negative lymph node biopsy does not exclude this diagnosis. The retroperitoneal structures to be considered as the site for such a neoplasm are kidney, adrenal and lymphoid tissue.

Six months later her pain was still present but with noteworthy changes: it was centered in the left lower quadrant and periumbilical areas; it was crampy; it was aggravated by urination and defecation. Periumbilical pain suggests intra-peritoneal origin in the small bowel, while lateralization to the left lower quadrant suggests either parietal peritoneal or retro-peritoneal involvement in this area. The crampy nature suggests origin in a muscular tube. However, urinalysis was again unremarkable arguing against bladder or ureteral abnormality, and sigmoidoscopy and barium enema were negative, points against intraluminal or intramural rectal or colonic disease. Why then was the pain aggravated by urination and defecation? The patient remarked on lower quadrant tenderness. The change in size, shape and position of the bladder or rectum during voiding and the passage of stool could result in pain, if they caused distortion of a lesion which contained or involved pain sensitive structures. Furthermore, increase in intra-peritoneal pressure resulting from straining or palpation of the abdomen could also incite pain under the same conditions. Splenomegaly was noted at this time and in addition, a mass was detected deep in the left upper quadrant (possibly displacing the spleen anteriorly and inferiorly). Somewhat surprisingly, a pleuropericardial friction rub was heard and the heart rate, although variable, remained faster than 100 per minute—presumably sinus tachycardia. The patient was losing weight and vomited occasionally. She was anorectic and thus in negative caloric balance. Hypermetabolism as suggested by the tachycardia and sweating could also result in weight loss.

At this stage neoplasia and infection are most likely. Which of the infections causes an indolent process extending over several months? Absence of fever in the presence of infections in older persons is not rare. Tuberculosis, Brucellosis and Infective Endocarditis must be considered. Brucellosis usually causes fever, anemia, splenomegaly and variable systemic manifestations. However, there is insufficient support for such a diagnosis in this patient. Infective Endocarditis of several months duration usually results in valvular insufficiency, but the murmur described was faint and more likely related to rapid flow. Furthermore, after several months of activity, endocarditis is associated with tachycardia usually in the presence of fever, anemia or myocardial failure. However, none of these were present and one would have to explain the tachycardia on some other basis. Systemic embolism can cause crampy abdominal pain by resulting in an ischemic bowel but the other abdominal features in this case would be inexplicable by endocarditis. The friction rub would be even harder to explain on this basis. Tuberculosis can involve the peritoneum and related structures, causing many unusual clinical syndromes and can persist undiagnosed for months. Little or no pulmonary involvement may be detectable. More and more frequently tuberculosis is being found in older individuals. Extension through the diaphragm could have produced a pleuropericarditis. During her second admission the patient developed early morning sweating, a feature compatible with, but not typical of tuberculosis. Peritoneal seeding can result in bowel and bladder symptoms. Mesenteric granulomata can produce conglomerations which may simulate masses. Miliary involvement can cause hepatosplenomegaly. The results of pelvic examination and skin tests would be helpful in considering tuberculosis.

Of the neoplastic processes, two deserve discussion. Carcinomatosis peritonei could explain all the clinical features described in this case. Usually ascites co-exists, however. The primary source may be pancreas, ovary, colon or stomach. There is insufficient evidence, however, to point to any of these. Myocardial metastases are not rare but pericardial involvement is usually the result of extension from adjacent lung and such a pulmonary neoplasm would likely be detectable by chest x-ray. The second neoplastic process to be considered is lymphoma. Often originating in retroperitoneal nodes, it could account for all of the clinical data. Especially suggestive are the mass, splenomegaly, sweating, weight loss and tachycardia. The negative scalene biopsy early on is quite possible since the process may remain localized to the abdomen for some time. Biopsy of obviously *abnormal* structures is the most helpful approach in confirming this diagnosis.

Ten months after the onset of symptoms, the patient was started on glucocorticoids with resulting improvement. Presumably an inflammatory process was suspected. Had tuberculosis been considered, I.N.H. therapy would have been mandatory. However, after five or six months her general status deteriorated once more. The abdominal pain which never left her, became more severe and gastrointestinal symptoms, including diarrhea, were prominent. Although pale, her hemoglobin was normal and she again had bouts of tachycardia. The major change was a pulsatile, left upper quadrant mass with a bruit. Because the mass expanded and remained pulsatile it likely involved a vascular structure, or was a well vascularized lesion, rather than one which was transmitting pulsations from a contiguous vessel. The more likely possibility would be a well vascularized lesion, since aneurysms seldom reach the size of this lesion without rupture. Terminally she had dysphagia, regurgitation and vomiting and likely developed aspiration pneumonia.

Can the mass explain the entire course? Infections seldom produce such large vascular lesions and mycotic aneurysms are rare. The mass was probably neoplastic, with a rich blood supply (usually arterial). The initial

appearance of the main symptom, pain, and the major sign, a pulsatile mass, in the left upper quadrant and the absence of good evidence for disorder of intra-peritoneal structures, points to a primary lesion of the retroperitoneum in this area, that is, kidney or adrenal. Since most adrenal tumours are relatively small, renal cell carcinoma is more likely. These cancers can become large and metastasize haematogenously to lungs, liver, the other kidney and even the heart. They are frequently associated with hypermetabolism, and approximately 5% present as fever of unknown origin. They are characteristically vascular. However, hematuria, gross or microscopic, is usual. This argues against, but would not exclude the diagnosis.

Final Diagnosis: Renal cell carcinoma with retro-peritoneal extension, displacement of spleen, and myocardial and hepatic metastases.

POSTMORTEM FINDINGS

Gross Examination

The skin was pale and there was generalized wasting, especially of the extremities. A mass was present in the left upper quadrant of the abdomen.

A gastric ulcer 0.6 cm in diameter was seen near the pylorus. It was punched out in appearance, with hemorrhagic edges, and the base contained firm, white tissue. In addition, numerous small superficial ulcers less than 0.5 cm in diameter were present in the large intestine. The liver was slightly enlarged weighing 1530 gms but otherwise was normal. The pancreas was adherent to a large mass of tumour-like tissue. This tissue was firm, white and contained patchy areas of hemorrhage and necrosis. It had invaded the pelvis and medulla of the left kidney and appeared to have replaced the left adrenal gland. The left ureter was obstructed 1 cm from the pelvis by invading tumour. The right kidney and adrenal were normal. The tumour mass was also adherent to the aorta and had infiltrated the para-aortic and paravertebral lymph nodes with extensive involvement of adjacent nerves.

Microscopic Examination

The stomach contained a chronic ulcer with an undermined edge and granulomatous tissue formation at the base, but no evidence of malignancy.

The right renal vessels showed moderate arteriolar and arterial thickening and the right kidney contained a few sclerosed glomeruli and some interstitial fibrosis. The left kidney displayed evidence of diffuse, acute pyelonephritis with marked edema and infiltration by polymorphonuclear leukocytes.

The right adrenal was normal. The left adrenal was replaced by small, dark, pleomorphic cells with frequent mitoses and some large, bizarre multinucleated cells. The cells, obviously malignant, were felt to represent a malignant pheochromocytoma.

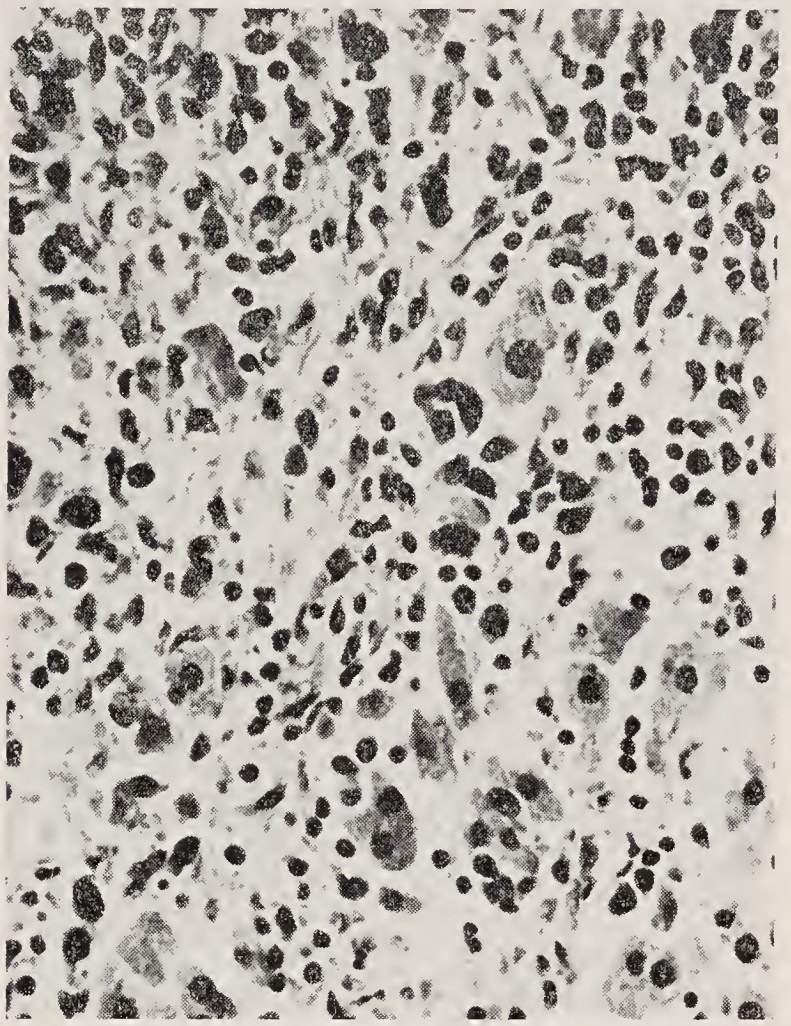

FIG. 1. Adrenal medulla (40X objective). Small, dark, pleomorphic cells and bizarre multinucleated cells are seen replacing normal medullary tissue.

PHEOCHROMOCYTOMA—DISCUSSION

Pheochromocytoma is a rare tumour which arises from the adrenal medulla or from chromaffin tissue located elsewhere in the body. It may be benign or malignant; functioning or nonfunctioning. Most are benign (less than 13 per cent are malignant) and most—benign or malignant—are functioning.

Tumours of endocrine glands such as the adrenal medulla are peculiar in that the functional disturbances which they produce are of greater importance, variety, and complexity than the neoplastic lesions themselves. The disturbances associated with pheochromocytoma are due largely to a secretion of catecholamines, primarily noradrenaline but occasionally a mixture of noradrenaline and adrenaline. Classically, the presenting symptoms are due to hypertension. There are three patterns of hypertension observed: *paroxysmal* hypertension produced by an intermittently secreting tumour; *persistent* hypertension produced by sustained secretion from the tumour; *a "metabolic syndrome"* characterized by less severe hypertension in the presence of diabetes and hypermetabolism. The commonest symptoms are headache, palpitation, and sweating. Other frequent symptoms related to a functioning tumour are nausea, vomiting, abdominal pain, weakness, weight loss, in-

tolerance to heat, nervousness, and tremor. These symptoms may be sustained or paroxysmal. Classically, on physical examination the patient is pale, perspires profusely, and is thin with evidence of recent weight loss (although pheochromocytoma has been demonstrated in obese people with no evidence of weight loss). The blood pressure readings frequently exceed 250/150, and a mass in the right or left upper quadrant is sometimes palpable. Hypermetabolism is evidenced by an increase in the B.M.R. and intolerance to heat, although the P.B.I. is within normal limits. Persistent albuminuria is common and hyperglycemia has led to a mistaken diagnosis of diabetes mellitus in some cases.

It should be stressed that the absence of such typical clinical features does not exclude a diagnosis of pheochromocytoma, for it has been termed "the great mimic", masquerading as such conditions as malignant hypertension, thyrotoxicosis, diabetes mellitus, myocardial infarction, biliary colic, acute pancreatitis, and generalized sepsis. A review of the literature reveals many cases which do not present with the typical signs and symptoms of pheochromocytoma, yet these findings can be explained physiologically and pathologically in terms of a functioning adrenal medulla tumour.

Fred *et al* described a case of pheochromocytoma which presented with symptoms of overwhelming infection. The patient had a high fever, hypotension, tachycardia, sweating, flushed facies, paralytic ileus, and a leukocytosis. The clinical impression was a gram-negative septicemia, yet this was not borne out by blood cultures. According to Fred, features suggestive of infection can be attributed partly or entirely to adrenaline secretion. Adrenaline elevates body temperature by augmenting cellular metabolism and by producing cutaneous vasoconstriction. The shock can be explained in terms of hypovolemia brought about by recurrent vomiting and by sequestered fluid in the bowel lumen, associated with extravasation of plasma into the interstitial space as a consequence of adrenaline-induced dilatation of precapillary vessels and constriction of postcapillary vessels.

In another paper, Moorehead *et al* conducted a study of 26 cases of pheochromocytoma. Presenting symptoms in his cases included paroxysmal hypertension, abdominal pain, manifestations of peripheral vascular disease, weakness and fatigue, chest pain, and a mass found on routine examination. Abdominal pain was the presenting symptom in 5 patients and a prominent feature in 8 patients. Three cases had no significant hypertension, although other signs and symptoms such as perspiration, nervousness, and a palpable abdominal mass were present. Moorehead explained the lack of significant hypertension despite the presence of a functioning tumour. He suggested that some small tumours less than 50 gms. have a rapid turnover of catecholamine stores providing a heavy infusion into the bloodstream. In other tumours the catecholamine stores are turned over more slowly, perhaps because a large portion is metabolized in the tumour. These tumours usually weigh more than 50 gms. and because the rate of secretion of active catecholamines per gram of tumour is low, they may escape clinical detection until of a significant size.

These examples from the literature substantiate the fact that a pheochromocytoma may present with unusual symptoms but yet can be explained in terms of a functioning tumour. To be certain of a diagnosis laboratory tests have been devised to effectively screen all patients suspected of having a pheochromocytoma. The determination of 24-hour urinary free catecholamines or the methoxy derivatives provides a safe and reliable basis for the diagnosis. Current chemical methods for determining urinary free catecholamines involve modifications of the trihydroxyindole method of Lund and an elevation of these substances is diagnostic of pheochromocytoma.

In summary, a case of malignant pheochromcytoma was presented. It presented with unsual clinical manifestations, including absence of hypertension; however, since the diagnosis was not considered we do not know if the tumour was functioning or not. We have seen from examples in the literature that a clinical diagnosis may be very difficult, due to the multiplicity of symptoms and signs seen in this condition. It was further pointed out that even atypical cases can be explained in terms of a functioning tumour.

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Recent Advances

Controlled Study Of Surgical Treatment Of Extracranial Cerebrovascular Occlusive Disease

INTRODUCTION

The integral and vitally important role played by the computer in medical research today comes to the fore in the American national cooperative study of extracranial cerebrovascular occlusive disease that is currently in progress. The Central Registry for this study is located in Dallas, Texas which draws data from 23 institutions from within the United States. The importance of this study can be realized by the fact that cerebrovascular disease results in at least 200,000 deaths every year in the U.S.A., ranking third among all causes of death in that country. In addition, at least another 2,000,000 people are currently handicapped by this disease.

Only as recently as the past 2 decades has it been appreciated that the vessels of the extracranial circulation (right and left internal carotid and right and left vertebral arteries) are playing a prominent role in the production of strokes. In patients subject to strokes, the incidence of significant lesions in the extracranial circulation varies between 50% and 60%; i.e., from one-half to two-thirds of cases will have significant extracranial disease. In one-third, the disease will be entirely intracranial.

AIMS OF THE STUDY

The specific aims of the current study of cerebrovascular occlusive disease are as follows:

1) To develop screening procedures to detect extracranial cerebrovascular disease

2) To determine the natural history of cerebrovascular disease after the nature and extent of the disease have been determined by complete neurologic, mental and angiographic evaluation

3) To determine the effects of various forms of therapy (medical and surgical) on the natural history of the disease
   a) To determine if surgery will prolong life
   b) To determine if surgery will increase the quality of survival, if not the duration
   c) To determine if surgery will decrease the frequency of transient or residual strokes

4) To determine the effects of cerebrovascular insufficiency and of surgical intervention on general mentation and intelligence, and to develop more accurate methods to assess changes in mental ability through neuropsychological techniques.

SELECTION OF PATIENTS

The patients considered for the study are those who meet the criteria for patient selection as set forth by the Central Registry in Dallas, Texas. These criteria are as follows:

1) Patients with histories suggestive of transient ischaemic attacks due to cerebrovascular insufficiency

2) Asymptomatic patients with physical findings of occlusive disease of the carotid, vertebral, subclavian, and/or innominate arteries, i.e., loud carotid bruits, blood pressure differences in the arms, etc.

3) Acute frank stroke patients whose neurological deficit is not so great as to preclude return to a non-institutional existence

4) Patients with chronic, stable, or resolving strokes who are candidates for rehabilitation.

5) Patients with progressing neurological deficits.

METHODS OF PROCEDURE

A. Investigation

Following a careful and detailed history of the subjective and objective content of the transient ischaemic attacks and a physical examination, including a complete vascular and neurological assessment, a clinical diagnosis is made, localizing the cerebral lesion to the area supplied by either the carotid or the vertebral-basilar system. In those instances where this is not possible, the attack is specified as non-localized. Clinical symptoms of carotid vascular disease include:

1) Unilateral weakness or paralysis
2) Unilateral paresthesias
3) Monocular visual loss or hemianoptic field defects
4) Aphasic disturbances
5) Partial amnesia and gnostic disturbances

Clinical symptoms of vertebral-basilar disease include:

1) Weakness or paralysis, often bilateral; occasional isolated monoplegia
2) Paresthesias, often bilateral
3) Vertigo, or the hallucination of movements with objects seeming to rotate or tilt
4) Binocular visual symptoms which may take the form of general blurring, or total visual loss in both eyes

5) Diplopia
6) Global amnesia
7) Dysphagia
8) Dysarthria
9) Syncope

The patients are next studied according to the protocol set by the Central Registry including serum cholesterol, EEG, EKG, skull films, cervical spine films, LP, psychological testing for intellectual impairment, and finally cerebral arteriography.

With respect to cerebral arteriography, it has been definitely concluded that four vessel angiography with attempts at complete visualization of both carotids and of the vertebrobasilar system is far superior to, and carries a much lower complication rate than incomplete studies visualizing fewer than four vessels. We believe the reasons to include:

1) Complete knowledge of the blood supply to the brain is a prerequisite to an intelligent surgical attack on the extracranial cerebral vessels, for during surgery, the vessel operated upon is temporarily clamped and hence, its supply to the brain is momentarily shut off.

2) Complete four vessel visualization can frequently be accomplished in one session without subjecting the patient to further unnecessary needle punctures, etc. at a later date. Further manipulative procedures imply a greater risk of complication.

3) The radiologist who develops a routine of four vessel visualization has the experience that naturally produces studies of the highest quality with the fewest complications.

B. Criteria for admission to the study

After the detailed workup is complete, patients fulfilling the following criteria are admitted to the study:

1) Satisfactory angiographic visualization of the entire extracranial and intracranial carotid and vertebral arterial circulation

2) Demonstration of an occlusive lesion which is surgically accessible and narrows the vascular lumen by 30% or more in the cervical portion of the carotid arteries, first portion of the vertebral arteries, the innominate, or the subclavian arteries proximal to the origin of the vertebral arteries.

3) Agreement by the vascular surgeon that surgical treatment is feasible, that the patient is a reasonable surgical risk, and agreement by the patient to have surgery if such is recommended.

C. Selection of Treatment

Patients accepted into the study are then selected for either medical or surgical treatment in a random fashion. Hence, selected patients have surgically accessible lesions removed and are given any medical treatment deemed necessary, and a numerically comparable group of patients are treated with the best form of medical therapy currently available—anticoagulation for those with suspected embolic episodes, control of blood pressure for those with hypertension, control of diabetes and other endocrine disorders, etc. Medical treatment is comparable in both groups and is considered to be the best that can be given for each case. Following the appropriate medical or surgical treatment, the patient is discharged to return in 2 months for a complete neurological, vascular and psychological followup examination, and thereafter at 6 month intervals for 5 years. Thus, comparison can be made between one group treated with the best available medical therapy plus surgical treatment (surgical group) and a second group treated with the best available medical treatment alone (non-surgical group). All data is recorded on IBM cards and sent to the Central Registry in Dallas where it is integrated and analyzed along with the data obtained from all other institutions participating in the study. If, before the scheduled date of termination of the study a statistically significant conclusion is made with respect to the best form of treatment for extracranial cerebrovascular occlusive disease, we will at once be morally obligated to discontinue randomization, for the study will then have fulfilled its major purpose.

CASE ILLUSTRATION

The following case will illustrate a typical patient who was randomized and treated at the San Francisco Veterans' Administration Hospital. Patient I.A.V. is a 60 year old white male who gave a history of several non-postural transient ischaemic attacks characterized by left sided weakness and paraesthesias (arm and leg). On two isolated occasions, he experienced the sudden onset of total blindness in the right eye that cleared within 30 minutes leaving no residual visual deficit. Twelve months prior to admission he experienced the sudden onset of a total left hemiplegia and paresthesias. He recovered except for residual weakness in the left leg. Arteriography on admission revealed a right internal carotid stenosis of 50% at its origin from the common carotid bifurcation, with significant post-stenotic dilatation, a right external carotid stenosis of 75%, no filling of the right anterior cerebral artery from the right internal carotid injection, and an intracranial embolus, presumed to have lodged in the right middle cerebral artery and to have arisen from the area of atheroma in the right internal carotid. The right anterior cerebral artery showed cross-filling from the left internal carotid. (See Fig. 1) The patient was randomized for surgical treatment.

The arteriographic findings at the carotid bifurcation were confirmed at surgery. Since his operation, the patient has had no new or recurrent symptoms of cerebral vascular insufficiency. His residual left leg weak-

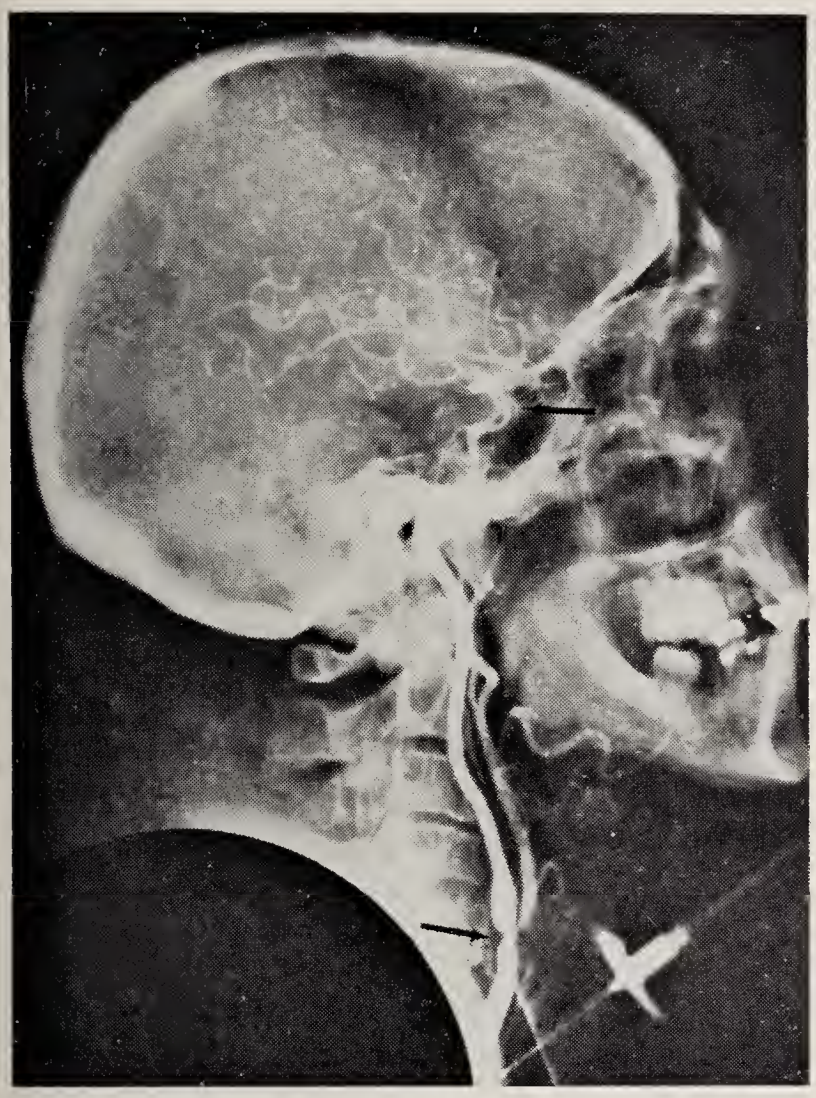

FIG. 1. Right carotid arteriogram for patient I.A.V.

ness has slightly improved, but there has been no change in mental status.

In ths case, it appears that surgery did prevent further transient ischaemic episodes but did not alter the patient's general mentation. In similar patients who have bilateral carotid disease, mentation seems to be improved by surgery.

Emergent trends

Since the data for the national study is still in the process of being analyzed, and since the study is scheduled to continue for a few years longer, statistically significant conclusions regarding indications for surgical versus non-surgical treatment of stroke are not as yet available. However, the following trends seem to be emerging from the data available at the San Francisco Veterans' Administration Hospital, whose individual study group now comprises 127 patients:

1. Surgery does not increase the patient's survival time. Most patients die of myocardial infarction before the effect of surgery on survival can be realized.

2. Surgery probably does, in selected cases, reduce the frequency of transient ischaemic attacks and possibly of severe strokes in the carotid circulation. It is felt that minor recurrent strokes in the carotid system are due to small emboli from atherosclerotic lesions and that major strokes are caused by either large emboli or complete occlusion by either thrombosis or hemorrhage under a plaque. In the posterior circulation, it is felt that non-postural ischaemic episodes are caused by emboli, but that postural episodes are caused by local blood flow disturbances and by cardiac arrythmias.

3. Patients with bilateral cartoid disease (stenotic lesions of 50% or greater) have the worst prognosis for functional survival but appear to stand a better chance for benefit from surgery. However, these patients have more widespread disease, and hence, the risk of complications of both surgery and angiography is greater.

4. Embolization from ulcerated atherosclerotic plaques in the extracranial vessels can produce the clinical picture of a transient ischaemic attack in the absence of significant stenosis, and hence, can mimic cerebrovascular occlusive disease. It appears that in these cases patients can be rendered completely asymptomatic by surgery.

5. It appears on follow-up examinations of patients with cerebrovascular disease that the degree of intellectual loss as revealed by mental status and psychological examinations is the best indication of the patient's ability to function in society rather than any physical deficit as revealed by neurological examination.

Looking to the Future

The neurology department represented by Dr. William E. Drake, Jr. and the psychology department headed by Dr. John Vitale at the San Francisco Veterans' Administration Hospital are currently embarking on a computer-oriented analysis of the data they have available from the patients studied at their hospital. They will soon be running a multi-dimensional cluster analysis on this data to establish the existing relationships among the neurological, angiographic, and psychological variables in patients with cerebrovascular disease. Hopefully they will elucidate the localization of psychological functioning in the brain more accurately than it has ever been done before, and will emerge with newer neuropsychological examining techniques with both clinical and statistical validity in terms of assessing disease.

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Fundamentals Of Radiologic Examination

The Chest

This is the second in a series of six articles. It concerns the radiologic examination of the chest, excluding the heart and great vessels which will be discussed next month.

ROUTINE CHEST FILMS

These are taken with the patient in suspended full inspiration. The *PA* (*posteroanterior*) chest film is the standard projection when the patient can stand and be positioned. The x-ray beam passes through the patient from back to front. It is best because the scapulae can be projected away from the lung fields by rolling the shoulders forward. However, when the patient is not ambulatory, AP views may be taken (often with the portable x-ray machine) in which the film is placed under the patient and the beam passed from above. These "portable" films are less informative than films taken by the larger machines in the X-Ray Department proper, since the developed amperage is lower. However, they are satisfactory for detecting gross abnormalities in extremely sick patients. Occasionally of course, erect AP views are also indicated.

In addition to the standard PA film, a left *lateral* view of the chest is usually obtained with the patient erect, arms overhead, film against the left chest wall, and the beam passing from right to left. At this point it is desirable to rectify a mistake that occured in the first issue. When two points of reference are given (eg. P and A) it means that the beam passes from posterior to anterior, but when only one point of reference is given, (eg. *left* lateral) it means that the film is against the left side. In either case, the part of the body *nearest the x-ray film* (in PA the anterior and in left lateral the left side) is in sharpest focus. Therefore, it may be seen that if pathology is suspected in the right lung, a right lateral projection should be specified.

Tomograms (PA, AP, and lateral) are an additional radiologic technique, sometimes of assistance in determining three-dimensional delineation and localization of a lesion initially seen on routine projections. These may best be thought of as "serial sections" of the chest (or any area desired) in which a number of x-rays are taken such that detail is best visualized at various designated distances from the chest wall.

Other views are occasionally indicated such as: *oblique* views, *apical lordotic* views (in suspected apical T.B.), *lateral decubitus* views (to detect minimal effusions), and *suspended expiration* films (to detect minimal pneumothorax and to study diaphragmatic movement).

DENSITY

In a radiograph, structures show varying degrees of radioopacity. The basic roentgen densities, in order of increasing density are: gas (air), fat, blood (fluid), muscle and calcium (bone). A normal chest film reveals gas density in the lung parenchyma, fat density in the subcutaneous tissue and breasts, superimposed fluid and muscle density in the heart and great vessels, and the calcium density of the bony structures.

METHODS OF EXAMINATION

A systematic approach ensures that no anatomic area will be overlooked. The sequence of thought when examining a radiograph should be "Is there a lesion?"; if so, "Where is the lesion?"; and finally, "What is the lesion?". The first question is often very difficult for the beginner because of the many variations of normal. The important thing for him is not to pass an *abnormal as normal.* Only in certain emergency situations is an immediate, localized, accurate diagnosis essential — usually, there is time to get an experienced interpretation, provided that the abnormality is noted. It should be realized in passing that if an experienced radiologist should interpret a *normal as abnormal,* then long, expensive investigation or useless, harmful therapy could result.

A useful routine for chest film is as follows:

1. The bony structures
2. The soft tissues
3. The mediastinal structures
4. The lung fields
5. The pleura and pleural space
6. The diaphragm and underlying structures.

I The Bony Structures

Beginning with the PA film, one studies the scapula, humerus, shoulder joint and clavicle. Observe the thickness and density of the bones; search for fractures, dislocations, and other skeletal abnormalities; most importantly, compare the two sides for symmetry. Note that because of their curved shape, the clavicles will appear symmetrical only if there is no rotation of the chest. When the patient is turned even a few degrees, the clavicles will exhibit marked asymmetry. Rotation is recognized by measuring the distance of the sternoclavicular joints from the spinous process of the vertebra between them. The distance will be unequal if the patient is rotated.

Next, examine the visible bony structures in the neck. Finally, the thoracic cage is studied with respect to

size, shape (especially significant are differences in one hemithorax) and symmetry. Then the individual ribs are studied from posterior to anterior, noting any abnormalities in contour as might appear in fractures, and localized changes in density as might occur in neoplastic infiltration, etc. Never rule out fractured ribs on the basis of routine chest films—special projections should always be ordered (designating the suspected area) in patients with chest trauma. Often of more importance than radiologically identifying fractured ribs is getting a chest film to rule out lung or pleural damage.

Notching of ribs from intercostal vessel dilatation is seen in coarctation of the aorta and some other conditions. Along with the ribs, the width and symmetry of the intercostal spaces should be evaluated. Abnormally wide interspaces, in association with radiolucent lung fields, depression of the diaphragm, and increased AP diameter is characteristic of obstructive emphysema.

On the PA film, the sternum, thoracic (dorsal) spine, and some mediastinal structures are superimposed and not well visualized (with the exception of spinal scoliosis). The lateral film is therefore used to examine these structures, in addition to assessing AP diameter and shape of the thorax. The dorsal vertebrae particularly should be examined for size, shape, density, and narrowed disc spaces. Radiologic interpretation of *intra*-thoracic pathology may depend upon the recognition of chest wall and spinal deformities which compromise respiratory and cardiac function.

In summary, it is important to not only look at, but "look under" the bones of the thorax since they may hide intrathoracic pathology.

II The Soft Tissues

The soft tissues of the neck, supraclavicular areas, chest wall (including breasts), and axillae, must be examined. Notice first if the tissues are scanty, indicating weight loss. In a female, be sure to check the breast shadows. A missing breast often means that the patient is being investigated for metastatic breast cancer. The nipples and areolae are occasionally seen and should not be mistaken for intrathoracic pathology. Another easily missed sign is air in the soft tissues of the neck, indicating surgical emphysema. Certain muscles may also be identified, particularly the pectoralis muscles and sternocleidomastoids (the latter may cast shadows across the medial aspect of the apices).

III The Mediastinal Structures

The examiner first notes the position and contour of the mediastinum from the PA film, checking for any shifting or bulges. He then proceeds to examine the mediastinum in detail using mainly the lateral film.

The mediastinum is a midline structure with clearly defined borders. Mediastinal shift is diagnosed from the PA film after noting the position of the trachea and cardiac apex. *Both* must be shifted to make this diagnosis (assuming that there is no rotation of the patient). Deviation of the whole mediastinum usually denotes intrapleural or intrapulmonary disease, whereas deviation of just the trachea points toward mediastinal disease.

Deviation of the mediastinum to the *same* side as the lesion occurs in fibrotic disease of the lung involving mediastinal pleura, and in atelectasis. Deviation to the *opposite* side can occur in massive pleural effusions, and pneumothorax. Tracheal deviation (and/or deviation of the aortic knob) is seen in such mediastinal conditions as aortic aneurysm and lymphomata.

The air-filled trachea is a midline structure extending from the lower border of C5 to the upper border of T5 or T6 where it bifurcates into the two main stem bronchi. It normally deviates slightly to the right at the level of the aortic knob just above the bifurcation. The right hilum is slightly lower than the left because the right bronchus is directed more downward than the nearly horizontal left bronchus. Other important radiological signs are tracheal compression and elevation of the right main bronchus.

Before one can assess the mediastinum, knowledge of the normal anatomic structures is necessary. Each area within the mediastinum should be examined carefully.

i) *Anterior Mediastinal Structures*

These include the inferior portion of the heart, the thymus or its remains, lymph nodes (internal mammary), and sometimes the thyroid and parathyroid glands. The anterior mediastinum in front of and above the heart is called the "anterior clear space" and should always be examined for lesions on the lateral film.

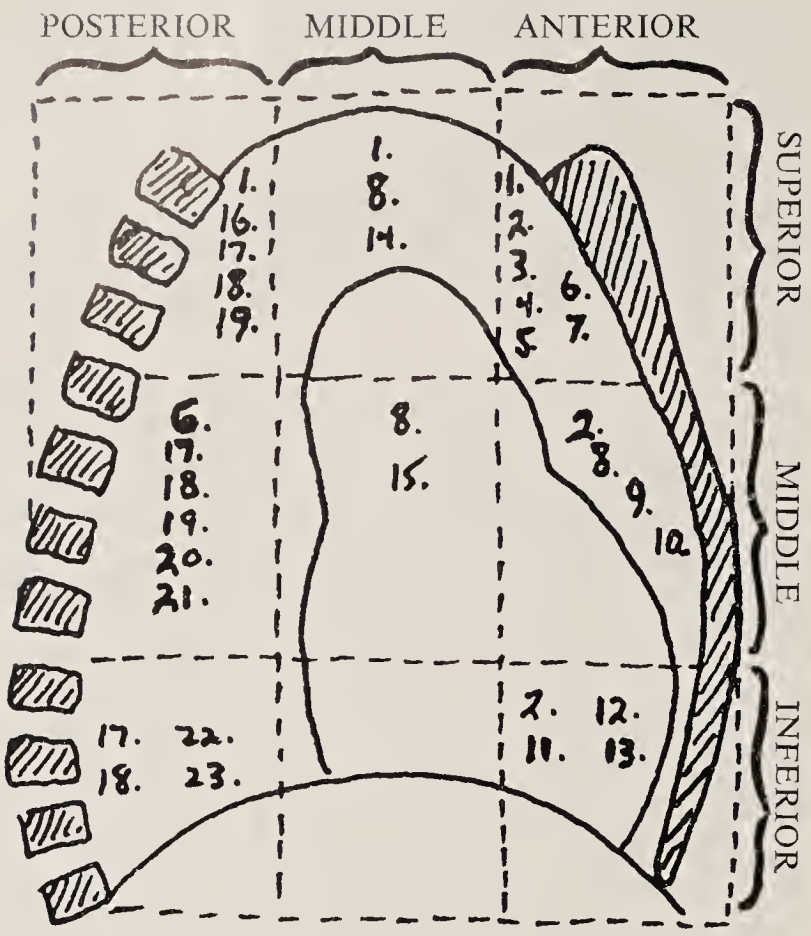
ii) *Middle Mediastinal Structures*

These include the heart, ascending aorta and great vessels, and lymph nodes.

iii) *Posterior Mediastinal Structures*

These include the aortic arch and descending aorta, the oesophagus, the trachea and main stem bronchi, hilar and paratracheal lymph nodes, the sympathetic trunk and vagus nerves. The area behind the heart is referred to as the "posterior clear space" and should always be examined.

Radiological lesions in the mediastinum are best classified with respect to the area where they most commonly occur. A diagram of the mediastinal subdivisions and the lesions found in them most commonly, follows.



THE LOCATION OF
MEDIASTINAL DISEASES

KEY TO ABOVE DIAGRAM

1. Aneurysms 2. Thymic enlargement (hyperplasia and tumours) 3. Lymphomata 4. Thyroid goitre 5. Parathyroid adenoma 6. Bronchogenic cysts (including tracheal cylindromas) 7. Myxomas 8. Dermoid cysts and teratomas 9. Mesodermal tumours (fibromas, lymphangiomas, haemangiomas, chondromas) 10. Enlarged internal mammary nodes (primary or metastatic) 11. Pericardial cysts 12. Foramen of Morgagni hernias 13. Mesodermal tumours (usually lipomas here) 14. Surgical emphysema 15. Lymph node enlargement due to exanthemata, granulomata, lymphomas or metastatic tumour 16. Pulsion deverticulum of oesophagus 17. Achalasia of oesophagus 18. Neurogenic tumours (neurofibromas and "adrenal rest" tumours of the sympathetic chain — neuroblastomas, ganglioneuromas, and pheochromocytomas) 19. Gastroenteric cysts 20. Meningocoeles 21. Thoracic spine tumours 22. Lesions of the azygous and hemiazygous veins 23. Foramen of Bochdalek and hiatus hernias.

Many ancillary methods are used in the radiologic examination of the mediastinum. These include barium swallows for visualization of the oesophagus and lesions compressing the oesophagus, and angiography, just to name two. Special radiologic techniques will be discussed in subsequent issues.

IV The Lung Fields

The PA film is best for visualizing pathology in the lung fields but the lateral is essential for localization. The *only* structures which appear in the lung fields on normal chest films (except fissures which, though they may appear to be in the lung fields, are not usually a problem because of their characteristic location) are BLOOD VESSELS — mainly Pulmonary Arteries. In pathologic films, other densities appear. These may be densities which come from structures normally situated in the lungs or may result from something being added to the normal anatomic structures. A short discussion of the anatomic structures follows:

i) *Blood Vessels*

These are normally seen on chest films and the problem is deciding whether the vascularity is increased or decreased; and if increased, does it involve both veins and arteries, or just arteries?

Vessels appear as linear, branching densities extending out from the hilar region and tapering towards the periphery where they are of small calibre and scarcely visible. It is at the periphery that enlargement of the vessels is most obvious. This may occur in left heart failure, mitral stenosis or in primary pulmonary arterial hypertension. Seen end-on, especially in the hilar region, vessels appear as circular densities which should not be interpreted as lesions.

Pulmonary veins tend to be larger in calibre, more tortuous than arteries and enter the left atrium anteroinferior to the hilum proper, where the arteries enter the lungs with the bronchi. In addition, enlargement of the veins gives a characteristic "rabbit ear" appearance extending downward to the left atrium from the upper lung fields bilaterally. Sometimes pulmonary angiography is necessary to differentiate between pure arterial and combined increase in vascularity.

ii) *Bronchi*

Bronchi and bronchioles, being filled with and surrounded by air, are not seen on normal films. The old term "bronchovascular markings" is therefore a poor one and should be avoided. The presence of visible bronchi is known as the *air bronchogram sign* and results either from consolidation of the air-containing alveoli around the bronchi as in pneumonia and pulmonary edema or from massive thickening of the bronchial walls as in peribronchial fibrosis due to chronic bronchitis or bronchiectasis. The air bronchogram may be helpful in other ways. Crowding together of the bronchi is seen in atelectasis, and dilated bronchi in bronchiectasis.

iii) *Lymph Nodes and Lymphatics*

Nodes are not seen in normal films because they are small and superimposed on the hilar vessels. If enlarged they appear as roughly circular structures which often overlap if several nodes are involved. They do not taper out into the lung fields as do hilar vessels. Lymph

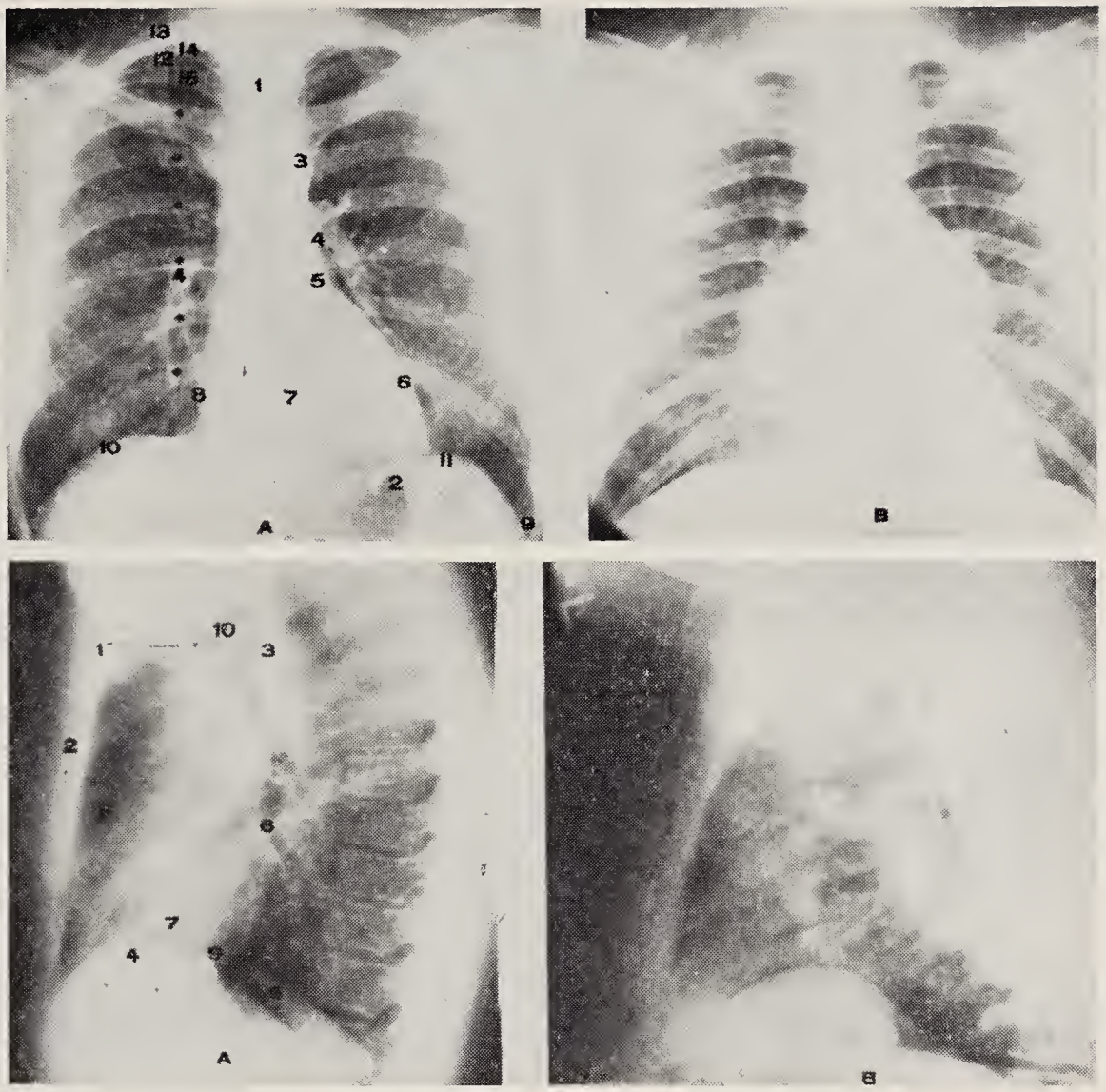


FIGURE 1.

A: Normal chest—PA view—42 yr. old male—with main radiological features. 1 - Air in trachea; 2 - Gas in stomach; 3 - Aortic Arch; 4 - Pulmonary Artery; 5 - Left atrial appendage; 6 - Left ventricular border; 7 - Right ventricle; 8 - Right atrial border; 9 - Costophrenic angles; 10 - Right diaphragm; 11 - Left diaphragm; 12 - 1st rib; 13 - 2nd rib; 14 - 3rd rib posteriorly; 15 - 4th rib posteriorly—arrows indicate subsequent ribs.

B: Abnormal (see text).

FIGURE 2.

A: Normal chest—left lateral view—42 yr. old male—with main radiologic features: 1 - Manubrium; 2 - Sternum; 3 - Scapula; 4 - Right diaphragm; 5 - Left diaphragm; 6 - Left atrium; 7 - Left ventricle; 8 - Right ventricle; 9 - Inferior vena cava; 10 - Trachea.

B: Abnormal (see text).

vessels are seen in two pathologic situations. The first, known as *lymphangitic accentuation* involves the intrapulmonary lymphatics and results indirectly from obstruction of the hilar or mediastinal nodes, or from direct engorgement of the lymphatics. The vessels appear as straight, non-tapering structures radiating from the hilum in stellate fashion. They are known as Kerley's "A" lines and are seen in inflammatory and neoplastic conditions of the mediastinum or lungs. The second, known as *lymphangiectasis* involves the subpleural lymphatics. These appear as transverse lines at the lung periphery and are only seen at the bases. They are known as Kerley's "B" lines and are seen in conditions of impaired lymphatic drainage (and in mitral stenosis for reasons we will not go into).

iv) *Fissures*

These may be seen normally as thin white lines. On the PA film only the minor fissure is seen extending out from the right hilum transversely to the pleura. On the lateral film both fissures may be seen. The major fissure extends obliquely downward and forward from the lower border of T-4 and intersects with the anterior diaphragmatic pleura. The minor fissure is seen as a transverse line at the level of the right hilum extending forward from the major fissure to the anterior lung border. Pathology of the fissures is discussed under Pleura.

RADIOLOGIC CLASSIFICATION OF PARENCHYMAL LESIONS

This classification is not invariable and there is much overlap, but it should serve as a guide.

A. Increased Density

1. *Ill-defined Homogeneous*

   a) Lobar or Segmental Distribution: eg. atelectasis, lobar pneumonia, pulmonary infarcts, sequestration.

   b) Scattered: eg. pulmonary edema, bronchopneumonia.

2. *Clearly-defined Nodular*

   eg. hilar lymphadenopathy, fluid-filled cysts, granulomata (tuberculosis, fungal) pneumoconiosis, hamartoma, abscesses, A-V fistulas, tumors—primary or metastatic.

3. *Linear*

   a) Accentuation of arteries: eg. inflammatory hyperemia, cor pulmonale, emphysema, pulmonary arteriosclerosis, L-R shunts.
   Accentuation of veins: eg. congestive heart failure, mitral stenosis.
   Accentuation of lymphatics: eg. lymphatic accentuation, and Kerley's "B" lines.

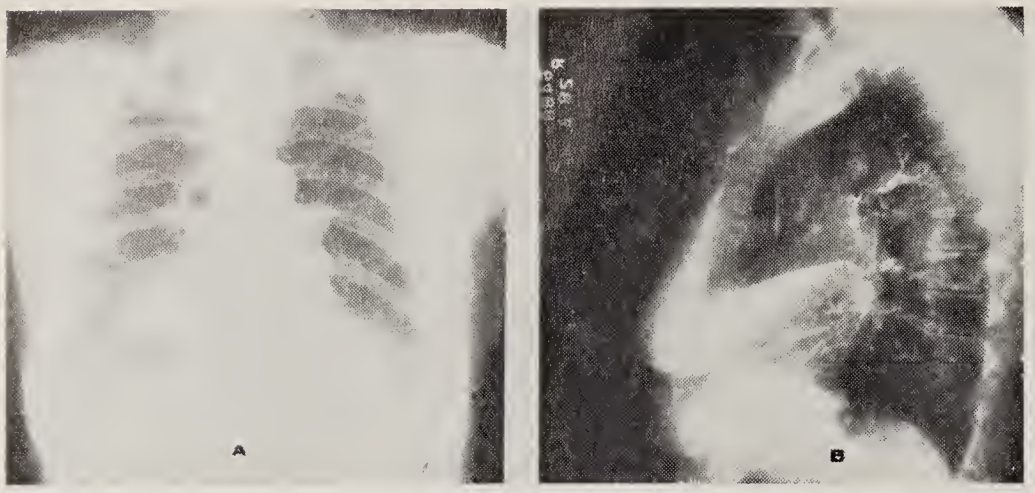


FIGURE 3.
A: Abnormal (see text).
B: Abnormal (see text).

b) Accentuation of bronchi: eg. peribronchial fibrosis, pulmonary (interstitial) fibrosis.
c) Platelike atelectasis.

B. Decreased Density

1. Pneumothorax
2. GI viscus in chest
3. Air-filled cyst or cavitation
4. Overdistension and/or breakdown of alveolar walls, eg. emphysema
5. Tubular radiolucency, eg. air bronchogram

C. Localization of Lesions

There are three main ways to localize a lesion:

1. *Anatomical Location*

This involves knowledge of lobes, segments, etc.

2. *Silhouette Sign*

This sign is very useful in radiographic localization. When silhouettes which normally have sharply-defined borders—especially the heart and mediastinum—become obliterated by pathology in the adjacent lung fields, it can be assumed that the pathology is at the same depth as the obliterated border. For example, obliteration of the right heart border by consolidation in the right middle lobe implies disease in this lobe, since these are both anterior structures. Similarly, obliteration of the upper right heart border and mediastinum means disease in the right upper lobe. Obliteration of the lower lobes will not result in obliteration of a heart border but in obliteration of the diaphragmatic silhouette. The minor fissure is another important landmark on the right side.

3. *Alveolar vs. Interstitial*

Alveolar lesions are produced by *intra*alveolar pathology. They have several characteristic features including: fluffy, ill-defined margins, a tendency towards confluency, replacement of normal air-containing lung, butterfly distribution with bilateral pathology in central and hilar regions, frequent presence of air bronchogram sign, lobar and segmental distribution, and shorter time between symptom onset and the appearance of radiographic lesions. Examples of alveolar lesions are pulmonary edema, pulmonary hemorrhage, broncho—and lobar pneumonia.

Interstitial lesions, on the other hand, involve *inter*alveolar pathology in the supporting tissue of the lungs. The appearance of these lesions varies from small, discrete nodulations to a linear, diffuse pattern. In either case the lesions have much more discrete margins than the alveolar type. Classically, some interstitial lesions are described as "honeycomb" in appearance but this term has been overworked and should not be used. One hallmark of interstitial disease is preservation of the air-containing lung which is compressed, not replaced. This accounts for the longer time between symptom onset and radiographic appearance of lesions. The more common interstitial lesions are TB (especially the miliary type), sarcoid, and pulmonary fibrosis in pneumoconiosis or ideopathic as in the Hamman-Rich Syndrome.

V The Pleura and Pleural Space

The "pleural space" is a closed envelope consisting of parietal and visceral pleura, and their reflections. The two layers are normally in close apposition and the pleural space is empty except for some thin, lubricating fluid. Pleura is not seen on x-ray unless it is thickened from fibrosis, calcified, or seen end-on—as it is in the fissures or when there is widening of the pleural space from air so that it is separated from the chest wall.

Pleural pathology is classified radiologically as: (1) widening of the pleural space, (2) pleural thickening and calcification, and (3) pleural nodulation. It is especially important to carefully look for an underlying pulmonary focus whenever pleural disease is seen, though this is not always present.

i) *Widening of the Pleural Space*

Air in the pleural space is referred to as *pneumothorax*. Small amounts collect high up over the apex and one sees the lung margin beyond which there is radiolucency, but no blood vessels. Expiratory films may be helpful in showing this up. A large pneumothorax reveals a lung collapsed against the mediastinum with mediastinal shift to the opposite side (especially in

tension pneumothorax). An inexperienced examiner may mistake the vertebral border of the scapula for a collapsed lung but from the criteria above, in addition to the same thing on the other side, this is hardly necessary.

Fluid in the pleural space is referred to as an *effusion* and may be due to transudate (hydrothorax), blood (haemothorax), or exudate (pus—pyothorax or empyema). One cannot detect effusions less than 250 cc. by x-ray and decubitus views are best for picking up small ones. Fluid first collects in the costophrenic sinus when the patient is erect and causes blunting of the costophrenic angle on the PA film. This sign is often indistinguishable from pleural scarring and fluoroscopy may be helpful, since fluid will thin out on inspiration, whereas scarring will not. As a greater amount of fluid collects, the upper border of the effusion will appear as a concave line curving upwards toward the chest wall, and the adjacent parietal pleura may cast a tapering, thickened shadow vertically against the chest wall. Massive pleural effusions may cause mediastinal shift to the opposite side and depression of the hemi-diaphragm on the ipselateral side. The entire hemithorax may appear radiodense in some cases. Effusions in the fissures may also be seen as elliptical shadows: major and minor on the lateral, and minor on the PA—the latter may actually be circular and simulate a "coin" lesion. On the PA film fluid in the major fissure appears as a diffuse homogeneous density because the fissure is seen en face.

ii) *Pleural Thickening and Calcification*

Pleural disease may be seen en face or in tangent (end-on). En face, the process may appear to be in the lung tissue and is better demonstrated end-on where it appears as a thickened line which obtusely blends with the adjoining pleura. Calcification, when seen en face, gives a characteristic stippled appearance against a homogeneous, cloudy background. The most common sites of thickening are the apices, the costophrenic angles, and the fissures. Pleural adhesions are bands extending from parietal to visceral pleura or from visceral to visceral in the fissures.

iii) *Pleural Nodulation*

Small pleural nodulations are not visualized unless there is air in the pleural space (for this reason a diagnostic pneumothorax may be done). If very gross, they may be seen in a normal x-ray. Nodulation is seen in neoplastic and granulomatous involvement of the pleura.

VI The Diaphragm and Underlying Structures

The two hemidiaphragms appear normally on PA films as smooth, "convex-upward" curves originating medially at the level of the tenth or eleventh ribs posteriorly. The right side is usually slightly higher anteriorly because of upward displacement by the liver, or downward displacement of the left side by the heart. As a result, two diaphragmatic lines are seen on the lateral film. Radiographic abnormalities of the diaphragm may be classified with regard to function, position, shape, and integrity.

i) *Abnormalities of Function*

These may be either: (1) immobility (fixation), or (2) paradoxical movement (upward on inspiration and downward on expiration). Usually, proper assessment of diaphragmatic movement requires fluoroscopy and other special views. We will not say anything further about this since true paradoxical movement is quite rare and the causes of immobility usually give other radiographic signs, discussed elsewhere.

ii) *Abnormalities of Position*

Bilateral elevation of the diaphragm is seen in obesity, failure of the patient to take a deep breathe, or increased intraabdominal volume from any cause, eg. ascites, third trimester pregnancy, hepatomegaly, bowel obstruction, etc.

Unilateral elevation of a hemidiaphragm is of considerably greater significance and may result from:

a) decrease in the size of the hemithorax, eg. lower lobe atelectasis,

b) faulty innervation of the diaphragm or intradiaphragmatic pathology, eg. phrenic nerve paralysis, diaphragmatic tumour, etc.,

c) pressure of abdominal contents upward, eg. gastric or colonic distension, hepatomegaly, free air or pus under the diaphragm, splenomegaly, etc.

If unilateral elevation is extreme, the mediastinum will be shifted to the opposite side.

Bilateral depression (and flattening) of a hemidiaphragm may be seen in asthenic individuals, or in conditions increasing the intrathoracic volume such as obstructive chest disease (chronic bronchitis and emphysema, acute asthma) or large bilateral pleural effusions.

Unilateral depression suggests unilateral obstruction of the airway such as partial occlusion of a bronchus by a neoplasm or a foreign body. An expiratory film will confirm the diagnosis if depression persists on expiration.

iii) *Abnormalities of Shape*

Irregularity of the diaphragmatic curve is referred to as "scalloping" or "tenting". It may be seen in normal individuals or in association with intrathoracic, diaphragmatic, or intra-abdominal pathology.

iv) *Abnormalities of Integrity*

The position and contour of the stomach "bubble" should always be noted. It normally lies close against the undersurface of the left hemidiaphragm, and on lateral films is a guide to it. If there is a defect in the diaphragm, the bubble may appear partially or wholly in the chest. The commonest cause of this is oesophageal hiatus hernia. Similarly, any portion of the GI tract may herniate into the thorax and appear as air bubbles or air-fluid levels; this is most commonly seen in infants with large congenital defects in the diaphgram and may present as an acute surgical emergency.

It should be noted that other upper abdominal structures should be examined. For instance, a valuable sign in association with pulmonary tuberculosis is calcification in the adrenal gland—alerting one to the possibility of Addison's Disease.

CASE HISTORIES

The reader should now have examined the "unknown" pathologic x-rays and have decided "where" and "what" the lesion is.

Case I (Figure 1 - B)

A 28-year old man was asymptomatic. A routine PA chest film revealed hilar and paratracheal lymphadenopathy. This is the classical appearance of sarcoid although frequently there is evidence of granulomata in the lung fields as well. This diagnosis was strengthened by the fact that the man was asymptomatic and that there were no chest signs.

Case II (Figure 2 - B)

A 72-year old man had his left eye removed 2 years previously because of malignant melanoma. The lateral chest film revealed many "cannonball" lesions in the lung fields. The radiologic diagnosis, confirmed at autopsy, was metastatic disease of the lungs from the primary in his eye.

Case III (Figure 3 - A and B)

A 67-year old female presented with a history of chronic smoker's cough for many years and several episodes of hemoptysis in the 6 weeks prior to admission. There were coarse rales over the lower right anterior chest. The PA film revealed obliteration of the right heart border by a triangular area of consolidation. This silhouette sign localized the lesion, therefore, to the right middle lobe. At operation, the bronchus to this lobe was found occluded by a bronchogenic carcinoma.

S. Langer 6T8

ACKNOWLEDGEMENT

I would like to express my gratitude to the Department of Radiology, Toronto General Hospital, for the use of their cases and equipment. Particular thanks go to Dr. I. E. Rosen for his time and effort in reading the manuscript and suggesting improvements.

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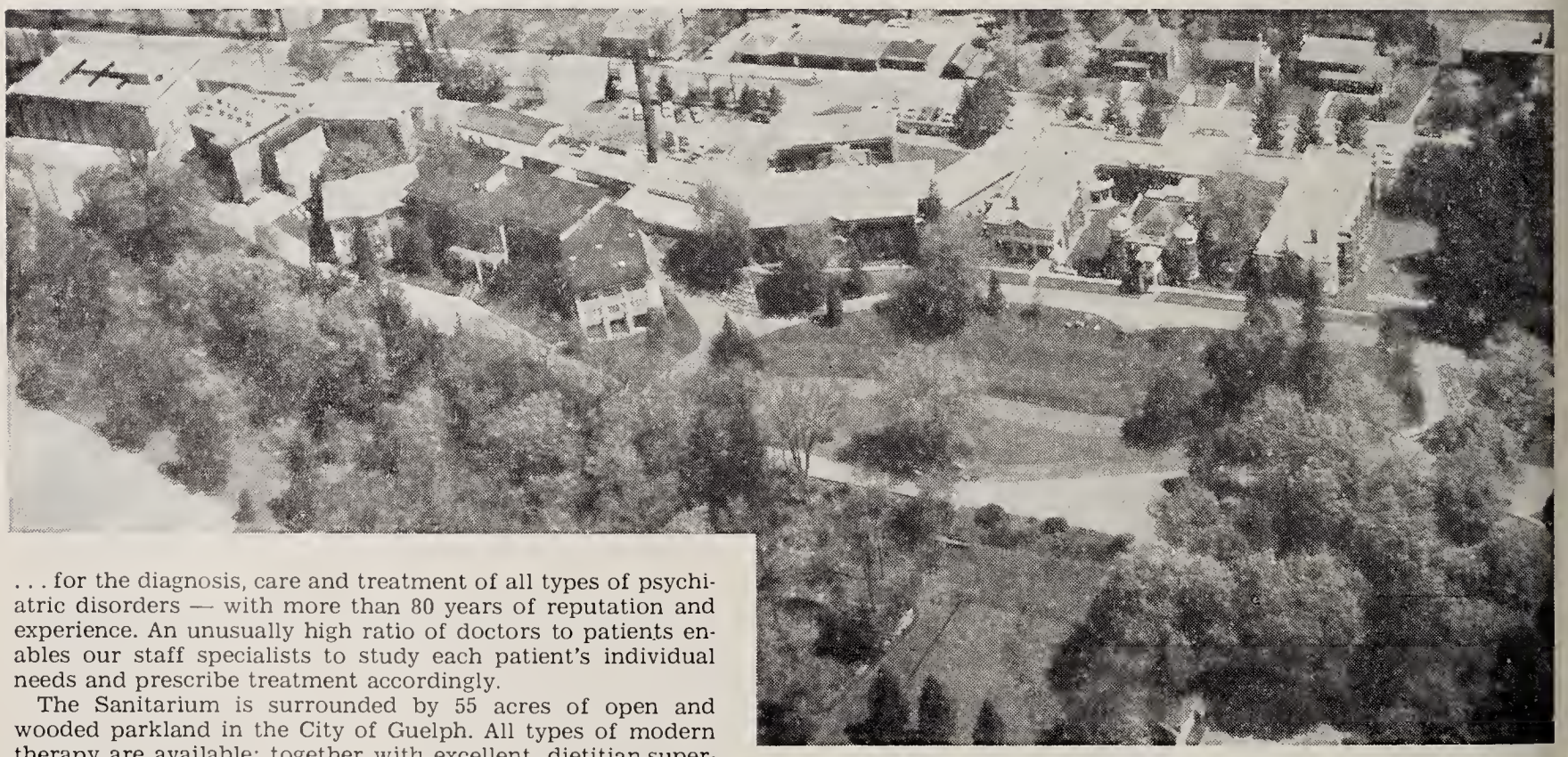

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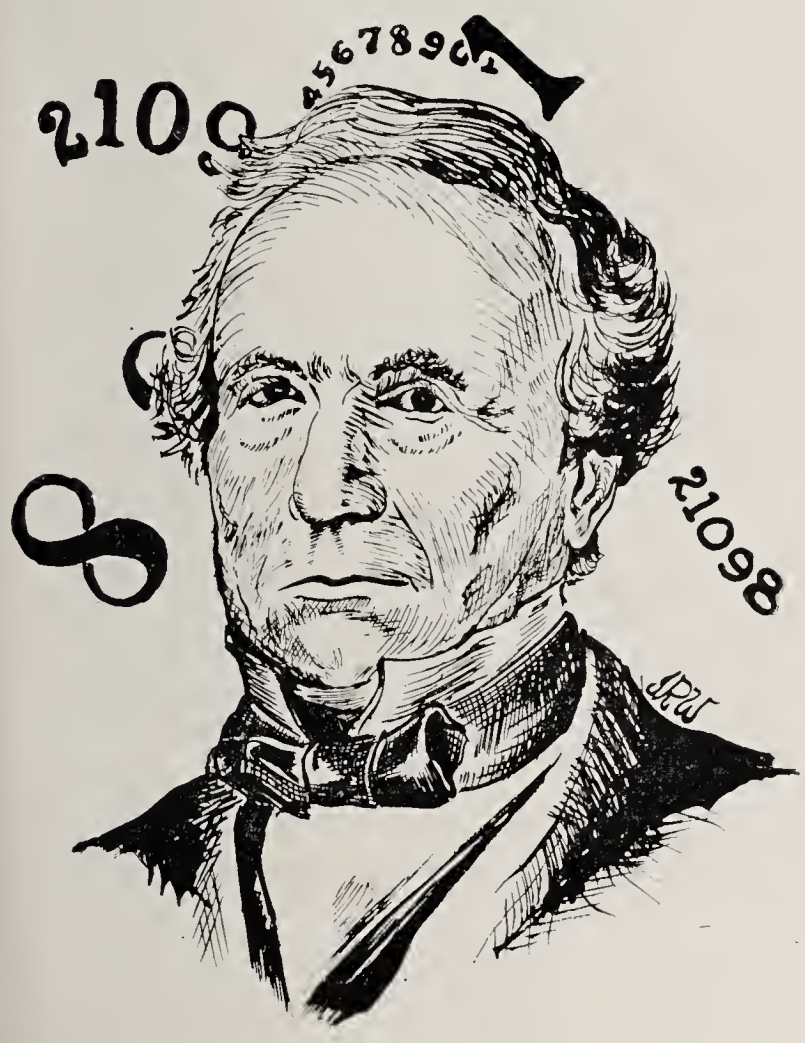

In examining the scientists and engineers of the last century, one finds that some of the greatest engineering works of all time were built in England by men who, by any standards, must be accounted among the most imaginative, far-sighted, and influential who ever lived. One of the most remarkable in this galaxy of talent was Charles Babbage—the father of the computer.

Born in Totnes, Devonshire, England in December 1791, Babbage lived to be almost eighty years of age. Much of his life, and a great deal of his money, was spent trying to develop a calculating machine which would be able to assimilate and process data far faster than could any human. Babbage, a perfectionist, never actually succeeded in finishing a working model of his machine (the first version of which he called the "difference machine" and the second, the "analytical machine"), but many of the theoretical ideas he worked out on paper have been implemented in the design of modern computers. Incredible as it is, he has been credited with understanding more about the logic of these machines than any other person prior to the end of the last war.

The amazing thing is that, despite being one of the most far-sighted men of his time, almost everything Babbage did provoked the derision and scorn of his contemporaries. His efforts to build his machine were considered futile, time consuming and absurd, and he was reviled for daring to assign to a machine, functions which could only be performed by the human mind. At one point he was even accused openly of the fraudulent use of government funds for the development of his "difference machine" when in actual fact he had supplemented these funds greatly from his own fortune.

Although much of his time was spent developing his machine, Babbage found time for a fantastic array of other pursuits. He originated what is today known as operational research; his analysis of the post office system led to the "penny post"; he studied insurance records and published the first reliable life tables and the first comprehensive treatise on actuarial theory; he invented the heliograph and one of the basic tools of medicine — the ophthalmoscope; he made a lifelong hobby of ciphers and deciphering and finally, was said to be able to pick any lock.

He was in many ways a strange man and a man of many contrasts. Once described as "one of the queerest fish that ever lived" it is difficult to know whether his oddities were responsible for his "failure" or his failure was responsible for his oddity. He was contentious, contrary, and cynical and was constantly at war with the establishment; his pet peeve was street musicians and organ-grinders whose racket (he had no ear for music) disturbed him while he worked. Despite these features he was lionized by London Society (much to his pleasure) for over forty years, for Babbage could also be sociable and witty, with a hearty ringing laugh and an unfailing supply of amusing anecdotes. He knew everyone of note in the poltical, social, scientific, artistic, and literary worlds of the day including the Prince Consort, The Duke of Wellington, Charles Darwin, John Stuart Mills, Thackeray, Carlyle, Browning, Tennyson, Longfellow, and Dickens.

At about the age of fifty, Babbage struck up a friendship with the Countess of Lovelace, the only daughter of Lord Byron. He was completely dominated by this young woman who, besides being one of the most charming and beautiful women of her time, was also a mathematical genius. She and Babbage tried to develop a method for winning at horse-racing, using statistics and probability theory, but the gambling became an obsession with Lady Lovelace and she fell deeply into debt. With her unfortunate death in 1852, Babbage was left to pay off her bookmaker.

"Born before his time" and "an unhappy, misunderstood man" are words that have been used to describe any number of brilliant men through history, and they apply very well to Charles Babbage who, despite his many successes, was considered an abject failure in his own time. If Charles Babbage could return to this world after almost one hundred years he would find himself acclaimed the genius that he knew himself to be, for in the past fifteen years his dreams have finally been realized in the development of the modern digital computer. Electronic devices, based on his own theoretical principles, have transformed his brainchild into practical machines able to respond instantaneously to given commands, and perform complex calculations at a rate undreamed of in his day.

In 1871 Charles Babbage died and was buried with few mourners save his son and the Duchess of Somerset. Alone and bitter at the end of his life, he was a man who would most likely be unhappy even if he lived today, when his ideas and inventions would be accepted immediately in our world of labour-saving machinery.

F. J. Bobik Orchard, B.Sc. 7T0

REFERENCE

Irrascible Genius — Charles Babbage, Inventor: Maboth Moseley.

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